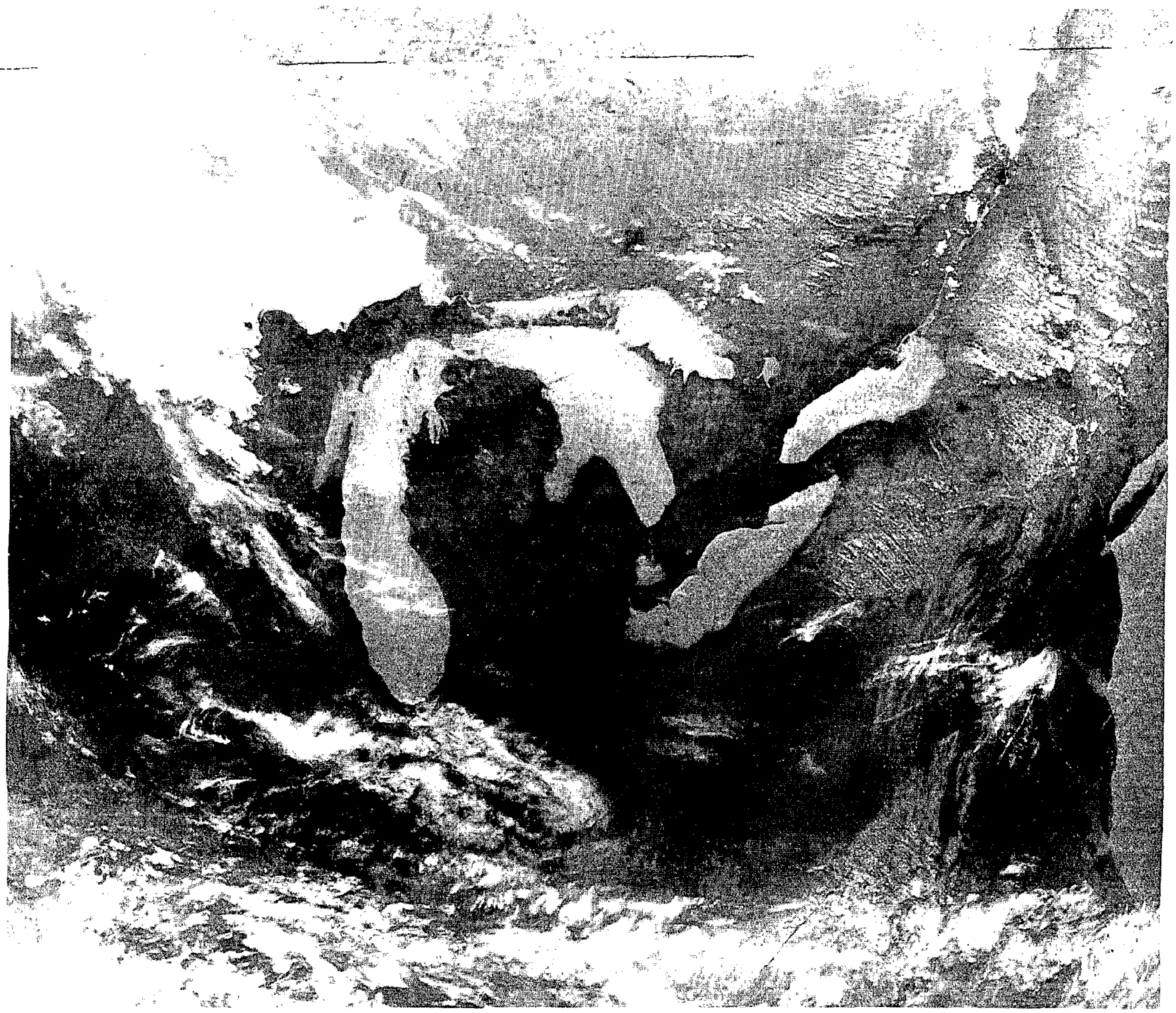
INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

Two Nations, One Lake–
Science in Support of
Great Lakes Management



Frontispiece. At 9:00 p.m. local time on June 14, 1973, the NOAA-2 satellite produced this infrared (10.5 - 12.5μm) image of the Great Lakes (darker tones indicate higher temperatures). The thermal detail in the lakes, as seen by the satellite's Very High Resolution Radiometer (VHRR; resolution is about 0.9 km) shows spring warming of the surface waters, a precursor of vertical stratification and the formation of a summer thermocline. While Lake Superior is obscured by clouds, upwelling of cold water can be seen in Lakes Ontario and Erie along the northern and western shores, a thermocline is just forming in Lake Michigan, and Lake Huron shows two interesting features - a large mass of cold water in its northeastern basin and the formation of a "thermal bar" along the Canadian shoreline south of Georgian Bay. This and other satellite images are part of the data gathered by IFYGL investigators. (NOAA National Environmental Satellite Service)

Two Nations, One Lake–
Science in Support of
Great Lakes Management

Objectives and Activities of the
International Field Year for the Great Lakes
1965-1973

Prepared by
John O. Ludwigson

for the

NATIONAL RESEARCH COUNCIL OF CANADA
CANADIAN NATIONAL COMMITTEE FOR THE INTERNATIONAL HYDROLOGICAL DECADE

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NOTICE

The project which is the subject of this report was approved by the Governing Board of the U.S. National Research Council, acting in behalf of the U.S. National Academy of Sciences. Such approval reflects the Board's judgment that the project is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the committee under whose guidance this project was undertaken and this report prepared were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. Responsibility for the detailed aspects of this report rests with that committee.

Each report issuing from a committee of the U.S. National Research Council is reviewed by an independent group of qualified individuals according to procedures established and monitored by the Report Review Committee of the U.S. National Academy of Sciences. Distribution of the report is approved, by the President of the Academy, upon satisfactory completion of the review process.

The Canadian contribution to the IFYGL was approved by the CNC for IHD, an NRCC Committee. This report has been reviewed through established procedures of the CNC/IHD.

PREFACE

The intricate relationships between science and management are acutely evident when they involve the use of major earth resources. This intricacy is exacerbated when the science and management are divided between two nations and concern a shared resource as indivisible as a lake.

The International Field Year for the Great Lakes, then, is an experiment not only in the scientific sense, but in the sense of trying to find new institutional ways for providing a base of scientific knowledge that will be adequate for the solution of managerial problems, even though the means for instituting those solutions are not yet clear. Thus, the Field Year is an important step forward in recognition of the need for a set of bi-national (or multi-national in other areas) institutions capable of effectively managing vital natural resources that must be shared by two or more nations.

It would be impossible to acknowledge individually the many people who have contributed generously and enthusiastically of their time and expertise to the Field Year for the Great Lakes. Some idea of their numbers may be gained from a glance at Appendix B. Many of these people also have been extremely helpful in the preparation of this report. We would like to acknowledge specifically the generous support - in terms of manpower, facilities, and encouragement, as well as finances - of the multitude of federal, provincial and state, and local government agencies, as well as the support of academic, independent scientific, and commercial organizations.

H. Garland Hershey
Chairman, U.S. National
Committee for the IHD

Major-General H. A. Young
Chairman, Canadian National
Committee for the IHD

TWO NATIONS, ONE LAKE - SCIENCE IN SUPPORT OF GREAT LAKES MANAGEMENT

Objectives and Activities of the
International Field Year for the Great Lakes 1965-1973

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MAN AND THE GREAT LAKES

INTRODUCTION

Canada and the United States share - about 40-60 - one of the world's largest and richest fresh water resources, the Great Lakes system (Figure 1). Not only are the lakes themselves large and valuable, but they are surrounded by a region of gentle topography, temperate climate, vast and rich mineral resources, and bountiful farmland. The lakes serve the region in many ways: as a source of fresh water, a means of transportation, a place of recreation, a source of food, and as an immense sink for the multiple wastes of an advanced industrial society. Moreover, through the St. Lawrence Seaway, opened in 1959, the lakes serve as a direct water link with the rest of the world, bringing trans-ocean shipping to the heart of North America.

Small wonder that in 1970, nearly 33 million people lived in or near the Great Lakes Basin - one of every three citizens of Canada, and one of every eight of the United States - and the total is still rising. Indeed, this favored region accounts for about one-fifth of the United States and one-half of the Canadian annual gross national product.

However, this great natural wealth, coupled with heavy human settlement of the region and continuing industrial development has made it increasingly necessary that both the natural processes in the lakes and the influences on the quality of their waters be understood and monitored to ensure their continued - and, perhaps, increased - value as a natural resource.

A large step forward in achieving this understanding of the natural physical, chemical, and biological characteristics of the Great Lakes is the International Field Year for the Great Lakes (IFYGL). The IFYGL Program has brought together a wide-ranging array of scientific resources, both human and technological, in a comprehensive study of one of the lakes, Lake Ontario. A basic premise has been that much of what would be learned in such a concentrated study would be applicable to the other Great Lakes, to large lakes in general, and to scientific understanding of the interactions of the atmosphere with large bodies of water (such as the oceans).

IFYGL is a joint program of the Canadian and United States National Committees for the International Hydrological Decade, a world-wide program of water studies and information exchange that began in 1965. The Field Year Program, which also roughly spans a decade, has been carried out by the coordinated efforts of public agencies and academic and private organizations in both countries. Both the data and analyses produced, will be available through IFYGL Data Archives in both countries, as well as in the scientific literature.

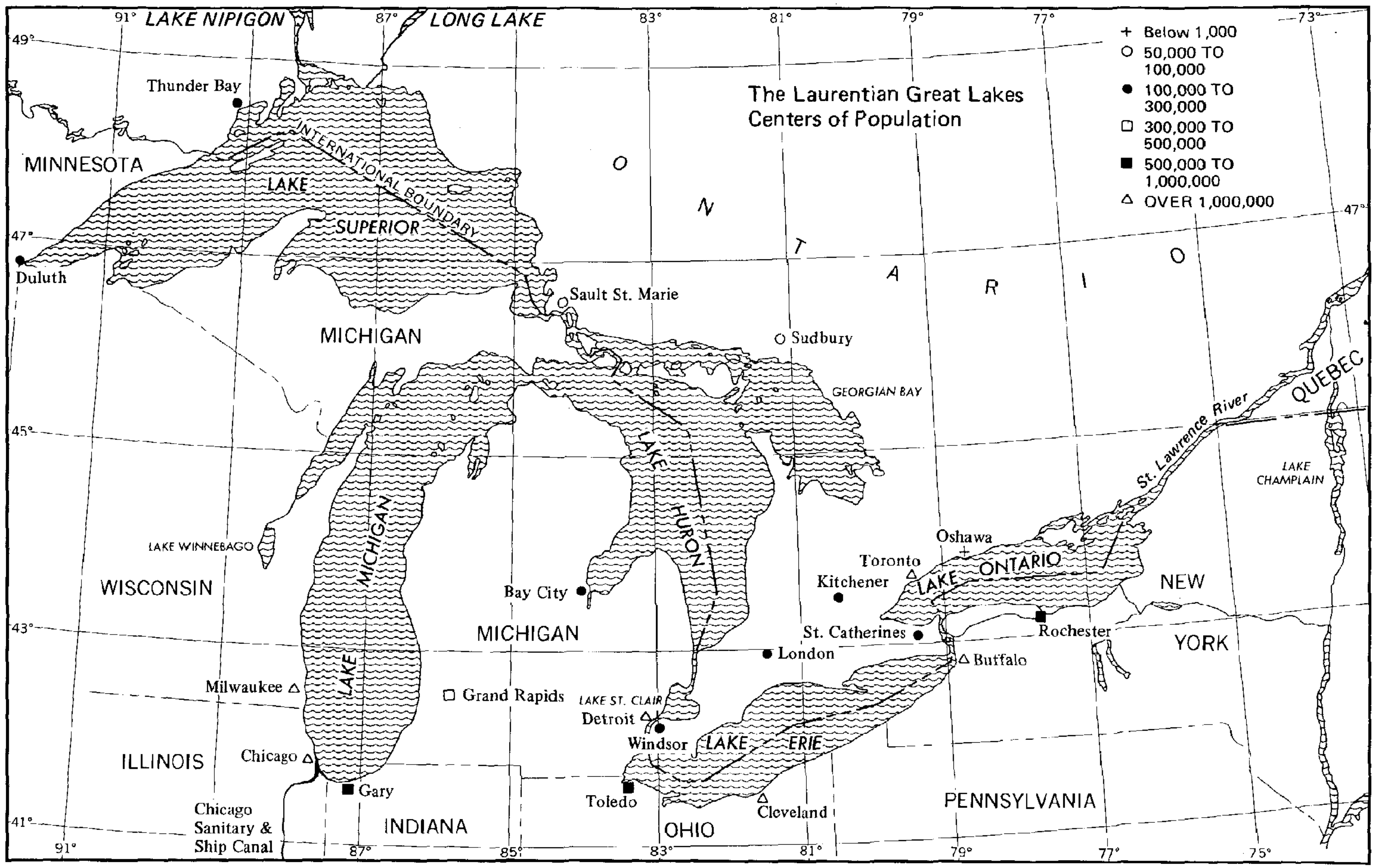


Figure 1. The Great Lakes region and selected centers of population. (modified from a map by the NOAA Lake Survey Center)

Because of the practical importance of the kind of knowledge sought in the Field Year, it seems appropriate to begin a history and overview of the IFYGL with a description of the setting - the area surrounding and affected by the Great Lakes of North America - its development, and some of its present and past problems.

THE GREAT LAKES REGION

Settlement of the Great Lakes region, a continuing process in both Canada and the United States, has placed ever-increasing demands on its abundant natural resources. Yet, until quite recently, there has been little change in man's approach to these resources since the free-wheeling frontier days of unrestrained exploitation. At that time, however, the natural resources of the region must have seemed inexhaustible - perhaps overwhelmingly so - to the first inhabitants.

The five Great Lakes themselves cover an area that is roughly 840 km (525 mi) from north to south, and 1,290 km (800 mi) from east to west. The shipping route from the St. Lawrence River to Duluth at the far western end of Lake Superior is approximately 1,930 km (1,200 mi); to Chicago, about 1,610 km (1,000 mi). The lakes Basin covers about 774,000 km^2 (299,000 mi^2) - roughly 60 percent in the United States and the rest in Canada. The International Boundary runs down the middle of all the lakes except Michigan which is wholly within the U.S. (Table 1).

In the seventeenth century, the region was covered with nearly continuous stands of virgin hardwood and pine trees. Fish were abundant: sturgeon, walleye, blue pike, burbot, smelt, bass, Atlantic salmon, whitefish, and the prized lake trout were important elements in the staple diet of explorers and settlers. Moreover, the waters of all the lakes were clean enough to drink directly.

Unknown to the early settlers, but later to form the basis of industry in the region, were the immense deposits of pure copper and unusually rich iron ore in upper Michigan and Minnesota, and of nickel and copper in Ontario. Beneath the waters of Lake Erie lay resources of natural gas and oil. One of the largest subterranean salt beds in the world stretches under that lake from Ohio to Ontario and west into Michigan.

The existence of the Great Lakes was first reported by a European in 1615 when Samuel de Champlain (then the Commandant of New France) arrived at the mouth of the French River in Georgian Bay of Lake Huron. (It seems likely that Champlain's scout, Etienne Brule, visited the lakes first, and more extensively, but he did not record his observations.) The lakes remained largely the province of explorers and missionaries until the late 1700's when the growing demand for furs in Europe turned the Great Lakes Basin into a land of opportunity for trappers and traders such as John Jacob Astor and the Hudson's Bay Company.

Table 1

DATA ON THE GREAT LAKES SYSTEM

GENERAL LAKE DIMENSIONS	Lake SUPERIOR	Lake MICHIGAN	Lake HURON	Lake ST. CLAIR	Lake ERIE	Lake ONTARIO
Length, right line in clear (km)	563	494	332	42	388	311
Breadth, right line (km)	257	190[a]	295[b]	39	92	85
Length of coastline including islands (km)	4,800	2,670	5,120[c]	272	1,380	1,170
Areas (km^2)						
Water surface, United States	53,400[d]	57,800[e]	23,700[f]	513[g]	12,900	9,220[h]
Water surface, Canada	28,700[d]	—	36,000[f]	756[g]	12,800	10,300[h]
Drainage basin land, United States	43,800[d]	118,000[e]	42,000[f]	7,380[g]	46,600	39,400[h]
Drainage basin land, Canada	83,900[d]	—	91,900[f]	10,600[g]	12,200	31,300[h]
Drainage basin land, total	128,000[d]	118,000[e]	134,000[f]	17,900[g]	58,800	70,400[h]
Drainage basin (land and water), total	210,000[d]	176,000[e]	194,000[f]	19,200[g]	84,400	90,100[h]
Maximum depth (m)	406	281	229	6[i]	64	244
Average depth (m)	149	85	59	3	19	86
Volume of water (km^3)	12,200	4,920	3,540	4	484	1,640
LENGTH OF OUTFLOW RIVERS[j] (km, approx.)						
St. Marys	113					
St. Clair			43			
Detroit				51		
Niagara					60	
St. Lawrence						808
SIGNIFICANT LAKE STAGES[k], 1860-1972 (m)						
Highest monthly mean elevation	183.51	177.38	177.38	175.47[l]	174.58	75.61
Lowest monthly mean elevation	182.34	175.37	175.37	173.69[l]	172.97	73.59
Mean elevation	182.99	176.39	176.39	174.68[l]	173.86	74.61
Average seasonal fluctuation	0.34	0.34	0.34	0.55	0.46	0.58
GENERAL HYDROLOGIC DATA, 1860-1972						
Average annual precipitation on lake and basin (cm/yr)	76.2	78.7	78.7	—	86.4	86.4
Mean outflow (m^3/s)	2130	1470[m]	5320	5350	5730[n]	6780
Highest monthly mean outflow (m^3/s)	3600	—	6850	6850	7190[n]	8890
Lowest monthly mean outflow (m^3/s)	1160	—	2800	2830	3280[n]	4360

a. Measured at wide point through Green Bay.
b. Measured at wide point through Georgian Bay.
c. Includes Georgian Bay and North Channel.
d. Including St. Marys River above Brush Point.
e. Lake Michigan including Green Bay.
f. Including St. Marys River below Brush Point, North Channel and Georgian Bay.
g. Lake St. Clair and St. Clair and Detroit Rivers.
h. Lake Ontario including Niagara River and St. Lawrence River above Iroquois Dam.
i. Maximum natural depth. Dredged navigation channel has 8.4 m depth.
j. Length shown under lake from which it flows.
k. Elevations above mean water level at Father Point, Quebec, on International Great Lakes Datum (1955).
l. Period 1898-1968.
m. Estimated flow through Straits of Mackinac; does not include diversion at Chicago into Mississippi River basin.
n. Does not include diversion from Lake Erie to Lake Ontario through Welland Canal.

[modified from chart NOAA HO 26-611 (11-71), Lake Survey Center, National Ocean Survey, NOAA]

SELECTED METRIC-ENGLISH EQUIVALENTS

1 km = .6214 mi (statute)	1 m = 3.281 ft
1 km^2 = .3861 mi^2	1 cm = .3937 in
1 km^3 = .2399 mi^3	1 m^3/s = 35.31 ft^3/s

The Great Lakes region soon became - and has remained - one of the fastest growing regions of the "west", a growth based on exploitation of its natural resources, often with little care for the "side-effects". After the beavers, the next resource to be exploited was the timber. What the farmers didn't cut down in clearing the land for agriculture, swarms of lumberjacks cut to build the cities that began to dot the lakes shores. The lumber boom ended, as might have been expected, when all the trees were gone.

Clearing the land had two natural consequences. The first was the rapid development of agriculture - still an important industry - on the generally rich soils, aided by the ample rainfall and mild climate of the region. The second, unappreciated at the time, was the considerable modification of the water environment to the detriment of the fish populations of the lakes. This was due to the increased and more rapid runoff of rain water from the farms, carrying with it heavy loads of sediment from the unprotected topsoil, and to the blockage of fish spawning runs in the streams by dams built to provide water power for sawmills, gristmills and, later, small hydroelectric power plants.

The industrial prosperity that has lasted into the present began in the 1840's with the discovery of rich copper and iron deposits in the Upper Peninsula of Michigan near the southern shore of Lake Superior. Shortly thereafter, the incredibly rich Vermillion and Mesabi ranges of iron ore (hematite and taconite) were discovered in Minnesota, about 97 km (60 mi) from the western shore of Lake Superior. These discoveries, in turn, have been followed by the location of very large deposits of copper, nickel, zinc, and iron (and associated precious metals), cadmium and sulfur, and smaller, but rich, deposits of gold, silver, uranium, and lead in Ontario. Both countries also produce very large quantities of sand and gravel, crushed rock, and cement in the Great Lakes Basin. The gross value of minerals produced in the basin in 1971, for example, was about $1.2 billion in Canada, and $1.6 billion in the U.S.

Since the first Indian set out in a bark canoe, the Great Lakes have been an important avenue of transportation and commerce. It was the rise of the fur trade, however, that brought about the construction of the first navigational works in the basin - a canal and lock constructed at Sault Ste. Marie in 1797 by the Northwest Fur Company, a Canadian rival of the Hudson's Bay Company. The canal was 91 meters (300 ft) long, with a 12-meter (39 ft) lock having a total lift of only 3 meters (9 ft). The remainder of the 6-meter (19 ft) drop of the rapids, the company decided, could be negotiated by its fur-carrying boats without aid. Their canal, on the Canadian side of the St. Mary's River, was blown up by U.S. troops in 1814 - a casualty of the War of 1812 - and was never rebuilt.

Construction of the New York State Barge Canal (the "Erie Canal"), completed in 1825, brought a new flow of settlers to the region. In 1834, about 80,000 persons passed through Buffalo on their way west. On November 27, 1829, the Welland Canal opened in Ontario, bypassing Niagara Falls to link shipping on Lake Erie with Lake Ontario. In the 1840's, the canals and locks that had been built along the Canadian side of the St. Lawrence River in the 1780's and enlarged in the early 1800's were uniformly deepened (to 3 meters) and improved, for the first time opening the Great Lakes to small ships from the Atlantic Ocean. A second round of improvements in the early 1900's provided a uniform channel depth of 4.3 meters (14 ft), equal to the Welland Canal then.

On June 18, 1855, the forerunner of the present "Soo" locks and canal was opened on the U.S. side of the St. Mary's River as a direct result of the discovery of large ore deposits around Lake Superior. The works included a canal nearly 2 kilometers (1.2 mi) long and two locks, each 107 meters (350 ft) long and 21 meters (70 ft) wide - all built by hand in just two years' time. On August 14, the first ore-carrying boat locked through, bound from upper Michigan to Cleveland. Finally, in April 1959, the St. Lawrence Seaway - a joint Canadian/United States project - made it possible for the first time for most large ocean ships to steam directly into the Great Lakes. Its 8-meter (27 ft) minimum channel depths and 244-by-24-meter (800-by-80-ft) locks, combined with improvements to the Welland Canal and deepening of the connecting channels throughout the Great Lakes suddenly turned cities such as Toronto, Cleveland, Chicago, and Thunder Bay into world seaports. The total tonnage of shipping that moved through Great Lakes ports in 1971 was about 190 million metric tons (209 million short tons) in the U.S. and 70 million metric tons (77 million short tons) in Canada (Ontario).

Yet, navigation on the Lakes has never been quite as safe and simple as one might think. The first ship on the lakes, the Griffon, built by Rene Robert Cavalier, Sieur de La Salle near Niagara Falls in 1679, made one trip to Green Bay, then disappeared forever on its return voyage. The worst storm ever to hit the area, in November 1913, sank or severely damaged more than 70 large lake ships. During IFYGL, operations were disrupted on more than one occasion when Lake Ontario became too rough to permit servicing the data-gathering buoys, and even the largest ships were forced to return to port because they could not continue data collection operations (although they could have ridden out the storm).

With the generally-increasing shipping on the lakes (in increasingly deeper-draft ships), it became apparent that better navigational charts were needed. The first surveys for this purpose on the Canadian side were conducted by the British Royal Navy, which did all Canadian hydrographic work up until 1883, when Canada began to take over this function. Since 1911, the Canadian Hydrographic Service (now a branch of the Marine Sciences Directorate, Department of the Environment) has carried out all Great Lakes hydrography and charting.

On the U.S. side, the first surveys were produced by the U.S. Army Topographical Engineers in 1841. Upon completion of the charting, the surveying unit was disbanded, only to be reconstituted in 1901 as the U.S. Lake Survey of the Army Corps of Engineers and charged with revising and improving the earlier charts. On October 3, 1970, its charting, research, and information functions became the Lake Survey Center of the newly created National Oceanic and Atmospheric Administration in the Department of Commerce.

In addition to food, water, recreation, transportation, and waste disposal, the rivers and streams of the Great Lakes system provide very large quantities of hydroelectric power to serve the surrounding region. Hydroelectric power plants are to be found from one end of the basin to the other, although the greatest capacity exists at Niagara Falls and the Moses-Saunders power dam on the St. Lawrence. In the Lake Ontario basin, including both those sites, there are 55 hydroelectric generating stations on the U.S. side with 3,122,404 kilowatts installed capacity, and, on the Canadian side, 19 stations, with 3,123,700 kw installed capacity. The remaining hydro-power potential in the Lake Ontario basin is relatively small, an estimated 260,290 kw capacity in the U.S. and 447,920 kw in Canada.

With an economic base in the mineral and shipping industries, some of the richest farmland on the continent at its back, and the world at its door, the Great Lakes community has flourished. Its present population, around 33 million, is expected to grow to more than 60 million by the turn of the century. By that time, most of the inhabitants of the region will be living in a bi-national megalopolis containing more than a third of the population of Canada, and a fourth of that of the United States.

PROBLEMS OF THE LAKES

This growth, however, has also placed considerable pressure on the natural resources of the Great Lakes region, especially the water resources - lake, stream, and underground - and the fish. In many cases, like the original stands of timber, these have been used with the assumption that there was no limit on their natural ability to renew themselves in both quantity and quality. As a consequence of this attitude, Lake Erie has been brought to an advanced state of eutrophication, Lake Ontario is also degraded, and the other lakes and their connecting channels are visibly marred with industrial wastes, sanitary sewage, heavy algal growths, undesirable fish species, and other problems.

At first, with few people and only the first stages of industrial development to contend with, the Great Lakes did have a very large relative reserve capacity to support human activities and recover from even very large introductions of pollutants. Today, however, with the advent of large steel ships, heavy industry, and an incipient megalopolis, the balance has changed: nature has long since been "conquered" and now must be managed and, in some cases, restored to health.

The problems of the Great Lakes can, to a large extent, be summed up in two categories: water quantity and water quality. Water quantity problems (Figure 2) show up in such forms as eroding shorelines, flooding, low water in ship channels, damage to marinas and other coastal facilities, or cutbacks in production at hydroelectric plants. For example, in 1972, a year of record precipitation within the Great Lakes Basin, many square kilometers of low-lying coastal land was flooded. Particularly severe flooding was experienced in areas of Ohio and Ontario near the shores of Lake Erie and Lake St.

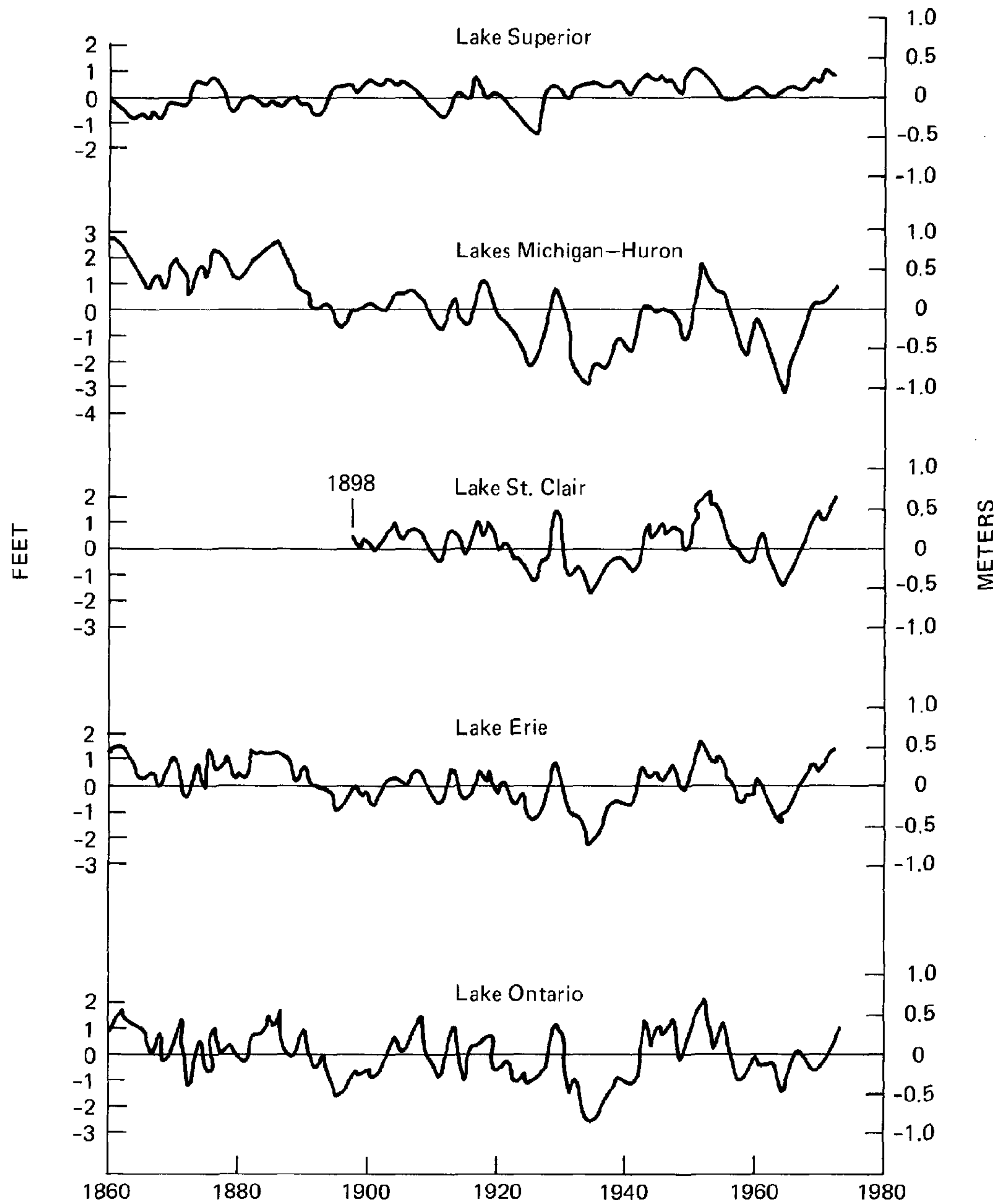


Figure 2. Lake-level variations (through 1972) from long-term average since data collection began in 1860. The values used in this chart are annual averages, and do not reflect the extremes that levels may reach in any given year. (NOAA, Lake Survey Center)

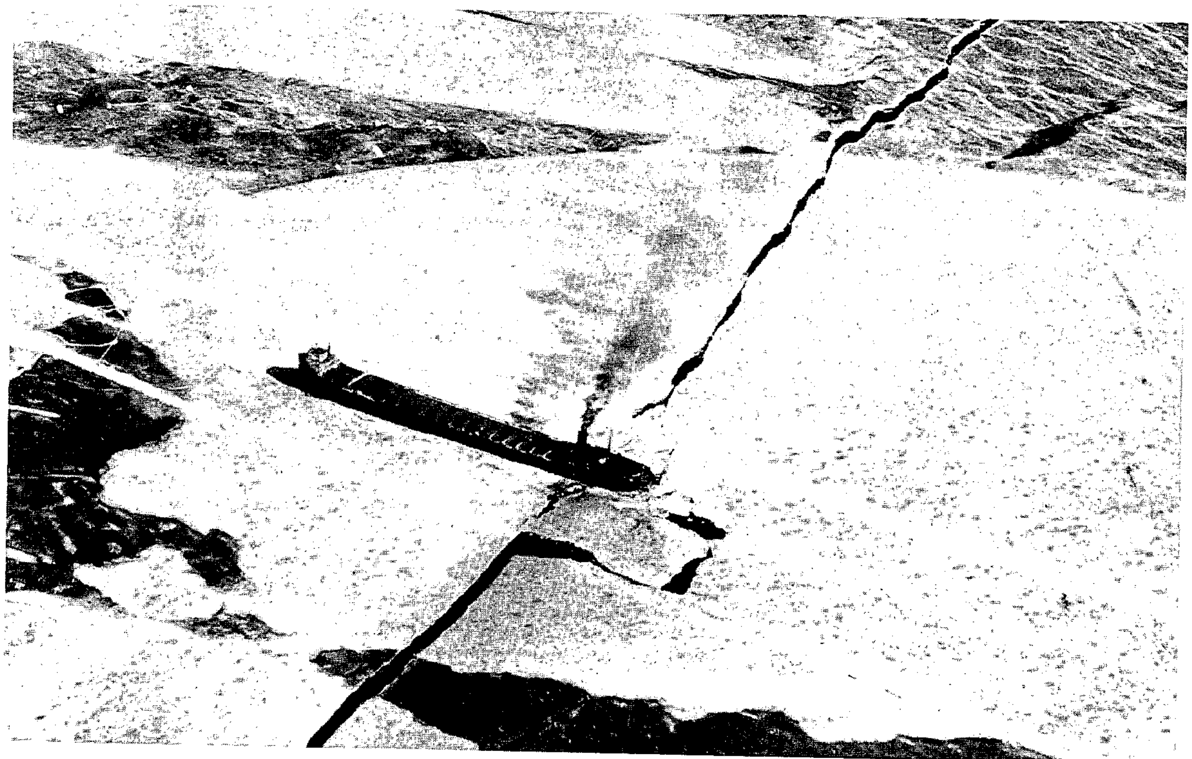
Clair, where many residents were forced to flee from their homes as wind-driven lake waters flowed far inland. In other years, these same people have seen their boat docks left high and dry when lake levels dropped. On the other hand, shipping interests found the high lake levels enabled them to load hundreds of thousands of additional tons of cargo, with a consequent massive windfall of profit. This is offset, however, by the losses they incur in low-level years when cargoes must be trimmed so the ships do not run aground.

The levels of the Great Lakes are mainly the result of meteorological factors, owing to the tremendously great size of the lakes in relation to the outflow capacity of the rivers. For example, to dispose of an extra 2.5 cm (1 in) per day of rainfall over Lake Ontario, as it fell, would require nearly doubling the flow capacity of the St. Lawrence River. In practice, an extra inch of level on the other, unregulated, lakes has a negligible effect (1,000 to 2,000 ft^3/s) on the river flows, which are more affected by meteorologically-stimulated water level changes. Thus, the lake level at any given point is a complex function of rainfall, evaporation, wind tides, barometric pressure, water storage capacity on and in the basin land area, inflow from the lakes above, and outflow.

A major problem that affects many uses of the Great Lakes is the formation of a winter ice cover on the lakes that may vary in extent from a few meters of shore-fast ice to a solid sheet over an entire lake (Figure 3). Even when there is little or no ice on the lakes themselves, ice in their connecting channels effectively precludes inter-lake winter navigation (the navigation season varies, but is around 250 to 260 days per year). Ice can also severely limit the quantity of water available for hydroelectric power generation (installation of an ice boom in the Niagara River has reportedly eased this problem there) and otherwise restrict lake outflows.

It has been suggested that the waste heat in the effluent from the increasing numbers of thermal-electric (both fossil- and nuclear-fueled) power stations along the lakes' shores could be utilized to extend the navigation season. Assessment of such a proposal requires a thorough knowledge of the factors influencing ice formation and decay and ice movements, as well as consideration of the effects of the added heat on other facets of the aquatic environment.

Water quality problems, especially on Lakes Erie and Ontario, are apparent to any visitor to the shore. Among the more serious, and obvious conditions are the widespread occurrence of unprocessed or only partially reduced human sewage (a public health as well as esthetic problem), and generally accelerated eutrophication. These conditions have resulted in considerable economic losses: closed swimming and sport fishing areas - recreation was, and is a major lake-shore industry - a diminished commercial fishery, and increases in the costs of providing municipal drinking water and industrial water supplies (made worse by the presence of mats of filamentous green algae - such as Cladophora - that clog water intakes and produce undesirable tastes and odors in the water).



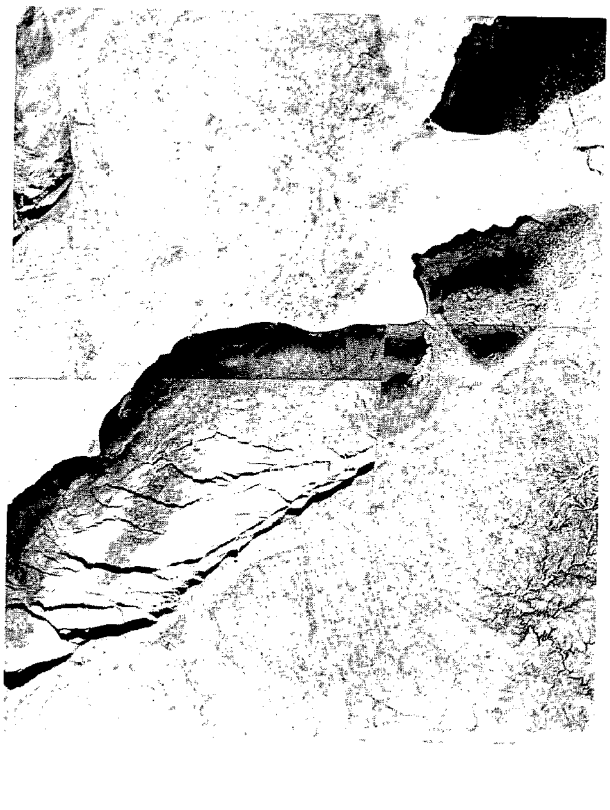


Figure 3. (a) A Great Lakes ore carrier battles the ice in Whitefish Bay, Lake Superior at the opening of the navigation season in April, 1968. (NOAA Lake Survey Center) (b) Large cracks have formed in the ice on Lake Erie over a 24-hour period under the influence of a 10-knot wind, although the air temperature is below freezing. This mosaic was made from ERTS-1 satellite infrared (0.8 - 1.1μm) images taken on February 17 and 18, 1973. (NOAA National Environmental Satellite Service)

These problems, again, are related to those of water quantity and movement. Pollutants are transported and dispersed by lake currents; their dispersal is also a function of the thermal structure of the lake, which, in turn, changes with season, location, and the prevailing weather. Thus, gaining an understanding of water quality problems requires concurrent study of water quantity problems.

A good illustration of the effects that human activities can have on the Great Lakes is the condition of the fisheries. While fish stocks of all the lakes have depreciated or changed in some degree since the region was settled, those of Lake Ontario are by far the most impoverished. In slightly more than 100 years, the more valuable stocks of lake trout, lake whitefish, Atlantic salmon (a land-locked form indigenous to Lake Ontario), and ciscoes have disappeared, leaving the lake populated mainly with American smelt and alewives.

The decline in the populations of the more valuable fish has been accompanied by (though not solely caused by) an increase in the numbers of sea lampreys, a species that, if not native to the lake, had colonized it before 1835. These eel-shaped fish are voracious predators of the more desirable fish, fastening onto them with their circular, toothy mouths and sucking out the juices.

Both alewives and lampreys have become major nuisances in the other Great Lakes as well, with the aid of man's navigational improvements. The alewives probably reached Lake Ontario from the Atlantic Ocean through the New York State Barge Canal (Erie Canal) in the 1860's, subsequently reaching Lake Erie and the upper lakes by the same means. Annual massive die-offs of the little fish have coated miles of shoreline with rotting, stinking fish corpses, removed at considerable expense to the taxpayers. Lampreys most likely reached Erie and the upper lakes through the Welland Canal. There, however, extensive control programs have succeeded in limiting their numbers.

Clearly, the changes in the fisheries can be attributed to man's influence. For example, over-fishing seems to be the single most important factor in the decline of the more valuable fish populations of Lake Ontario and Lake Erie (although scientists do not all agree on this). As the fish stocks collapsed, the fishermen increased the intensity of their efforts in a vain attempt to make up for the rapidly dwindling catches. The major destabilizing force arising from pollution (especially in Lake Erie) has been that of artificially accelerated eutrophication. A particular and increasing problem since 1950, this has resulted in heavy algal growths that smother fish spawning grounds, reduce oxygen concentration in the water (as the dead algae rot), and coat fishing nets.

The list of problems is a long one, and grows longer daily in response to the increasing and changing human needs in the region, and as understanding of the natural conditions and interrelationships there improves. The time when these problems could be addressed singly is long past; since each interacts with the others, often in ways that are poorly understood in the whole-lake context, they must be addressed in concert and the nature and variation of their interrelationships described as a first step toward making effective plans for their alleviation or elimination.

MANAGEMENT OF THE LAKES

The first "management" schemes (although greatly limited in scope and intent) were designed to support the growth of shipping in the Great Lakes Basin. Canals and locks were built, channels were dredged, and government agencies began to chart the waters for the benefit of the ever-larger ships navigating the lakes, such as the bulk cargo carriers coming down from Duluth and Thunder Bay to the steel mills along the shores of the lower lakes, and to transshipment points for foreign ports. These efforts were accomplished through a variety of individual federal, provincial, and state agencies, most of which were formed in response to specific problem areas as they were identified. While there was some cooperation among them, the multiplicity of political entities in the region hampered the taking of effective action on the scale that was often necessary.

By 1909, however, both Canada and the United States had come to the realization that the Great Lakes would have to be managed cooperatively if they were to continue to serve the ever-growing needs of the region. Accordingly, the United States and Great Britain (which then acted for Canada) negotiated and signed the Boundary Waters Treaty of 1909, describing the lakes and other shared waters and providing an organization to oversee their orderly development and management - the International Joint Commission (IJC).

The IJC was empowered to "... have jurisdiction over and ... pass on all cases involving the use or obstruction or diversion of the waters..." within the broad limits defined by the Treaty. Almost as an afterthought, the "High Contracting Parties" appended to Article IV the words that have become the basis for a recent (1972) expansion of the Commission's responsibilities and powers:

> "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other."

While the IJC was not specifically directed to concern itself with pollution at that time, it was given an order of precedence for the use of boundary waters that was to govern its actions in all cases. Most important was to be, "Uses for domestic and sanitary purposes." Second and third in importance, respectively, are "Uses for navigation, including the service of canals for the purpose of navigation;" and "Uses for power and for irrigation purposes."

Over the years since it was formed, the IJC has made a number of studies of both water quantity and water quality questions on the Great Lakes. One of its thorniest problems has been the assessment of the various proposals to control, in some way, the levels of the lakes. The continually-increasing use of the lakes for such purposes as shipping, electric power generation, and recreation has seemed to indicate that there might be considerable benefits in at least stabilizing the levels of the lakes.

One of the first things learned was that the relationships of water supply, outflow, and lake levels are not at all simple. Because the Great Lakes are very large in relation to the capacity of their connecting channels, and the land area of their drainage basins, even very large changes in water supply or outflow have only a small effect on lake levels. It is the buffering effect of this relationship that makes the Great Lakes-St. Lawrence System one of the best-naturally-regulated water systems in the world: maximum flows in the outflow rivers (including the St. Lawrence) are only about two or three times the minimum flows. (In contrast, the Mississippi River varies by a factor of about 30 to 1, and the Columbia River by about 35 to 1.) (Figure 4)

Moreover, the general difficulty of predicting the water supply to the lakes is compounded by the near-inability to measure directly (let alone predict) precipitation over the lakes themselves, or the evaporation from their surfaces. Evaporation has been estimated recently to be more than 15 x 10^{10} m^3/yr, or an average rate of approximately 4,780 m^3/s - a little less than the average flow of the Niagara River (5,490 m^3/s) and nearly 80 percent of the total direct input to the lakes surfaces from precipitation (Table 2). In addition, the runoff from the land area of the Great Lakes Basin is highly variable, and is changing in both quality and quantity as the basin population grows.

In more than 30 studies of Great Lakes regulation made since the turn of the century, no clear conclusion was reached as to whether or not the lakes should be regulated. One very difficult problem in many of these studies was the question of deciding whether the benefits of any given regulation plan would outweigh the costs (including both the costs of carrying out the plan, and the potential costs of damage to some users of the lakes). Interestingly, many of the studies made before 1950 considered only regulation of the lakes to higher levels than their natural range, a change that would principally benefit such users as shipping and hydroelectric power generation systems. However, higher lake levels, such as occurred in 1952, also accelerate the erosion of shorefront property, promote the flooding of low-lying areas and marine facilities, and undermine lakeside buildings. Studies made since 1950 have mainly considered limiting the fluctuation in levels, undoubtedly reflecting the influence of riparian property owners.

In 1964, the International Joint Commission formed the International Great Lakes Levels Board. The IGLLB was instructed to determine whether it is in the public interest to regulate further the levels of the Great Lakes and their connecting waters so as to reduce the extremes of stages. Their studies* found that some degree of regulation of the lake levels is technically feasible, but can be costly in relation to the benefits. (Outflows of two lakes are now controlled: Lake Superior since 1921, and Lake Ontario since the construction of the St. Lawrence Seaway in 1960.)

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* Regulation of Great Lakes Water Levels. A report to the International Joint Commission by the International Great Lakes Levels Board (under the Reference of October 7, 1964). 294 pp., December 7, 1973.

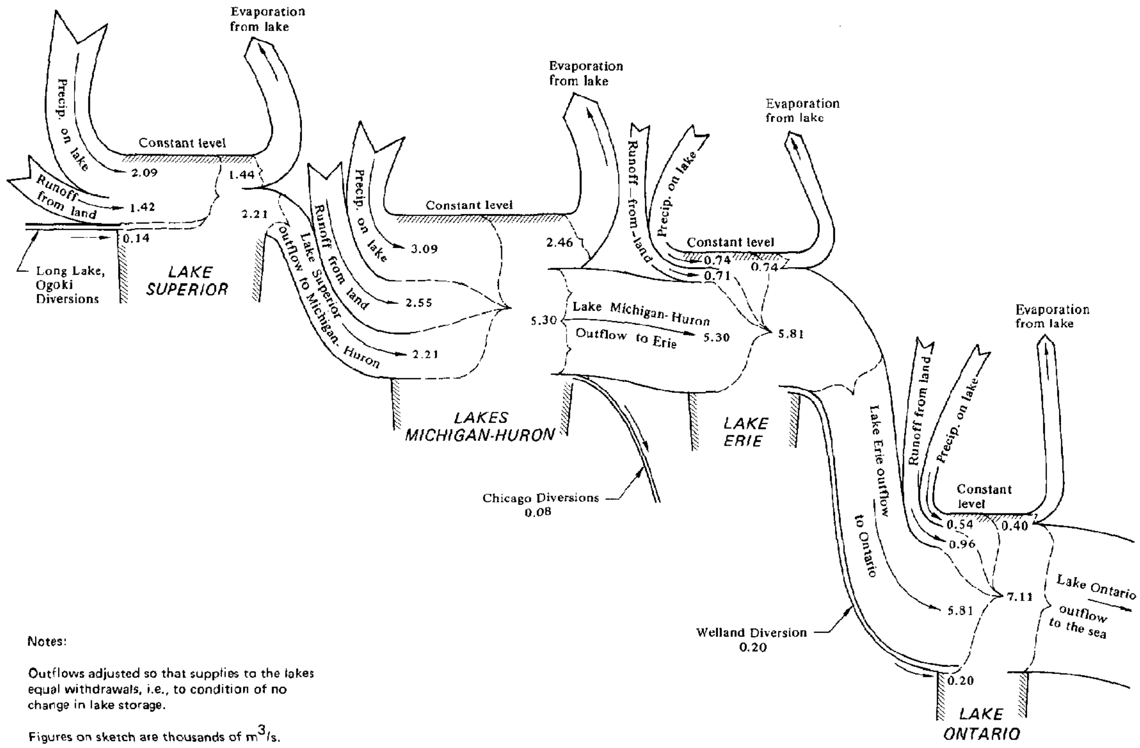

Figure 4. Inflows and outflows of water in the Great Lakes. (from: "Regulation of Great Lakes Water Levels," a report by the International Great Lakes Levels Board to the International Joint Commission, December 1973)

Table 2

AVERAGE LAKE SURFACE MOISTURE FLUXES

Evaporation from Lakes Surface	cm/yr*	m^3/yr (x 10^{10})
Superior 1/	45.72	3.75
Michigan 3/	57.91	3.34
Huron 1/	71.62	4.27
Erie 2/	90.93	2.33
Ontario 2/	71.62	1.40
Totals	337.80	15.09 (= 4,780 m^3/s)

1/ (1959-1968)

2/ (1950-1968)

3/ (1921-1950)

Precipitation on Lakes Surface (1900-1972)	cm/yr*	m^3/yr (x 10^{10})
Superior	75.44	6.19
Michigan	79.25	4.57
Huron	79.50	4.74
Erie	85.85	2.20
Ontario	87.12	1.70
Totals	407.16	19.40 (= 6,160 m^3/s)

Total evaporation = 78% of total precipitation.

*average over each lake's surface area.

(Compiled by P. P. Yee, Canada Centre for Inland Waters, personal communication.)

In the area of water quality, what is perhaps the earliest study on the Great Lakes was prompted by the prevalence of water-borne typhoid fever. Work was begun by the IJC in 1912 in response to a request from Canada and the United States. Their report, issued in 1918, concluded that pollution was "very intense along the shores of the Detroit and Niagara Rivers" and was clearly endangering the citizens of both countries in direct contravention of the Treaty.

International agreement on a cooperative restorative and protective effort, however, was not achieved until April 1972, when the two nations concluded a substantive agreement on action to preserve and restore water quality in the lakes, especially Erie and Ontario. The "Agreement on Great Lakes Water Quality" calls on the Commission to collect, analyze, and disseminate available information, coordinate research, investigate pollution sources, and report annually to the two nations on the progress made toward improving water quality.

The agreement was based on an IJC report, entitled "Pollution of Lake Erie, Lake Ontario, and the International Section of the St. Lawrence River" that was published in 1970. The IJC report, in turn, was based on the results of a massive study conducted, through public agencies in Canada and the United States, by IJC-appointed Water Pollution Boards for Lake Erie, and for Lake Ontario and the St. Lawrence River. The Boards presented the results of their study in three volumes totaling 800 pages. The disciplines involved in the work included bacteriology, biology, geochemistry, water chemistry, limnology, medicine, oceanography, physics, and several branches of engineering. It was, the Commission noted in its own report, "the most extensive water pollution study to be undertaken anywhere to date."

Having said that, the Commission went on to state the long-standing realization of the Great Lakes scientific community that: "Although available technology can remedy many of the pollution problems, solutions to many other problems cannot be prescribed at this time because the knowledge and understanding of the physical phenomena, chemical interactions and biological activities are woefully inadequate."

The IJC's conclusion did not mean so much that science on the Great Lakes has been neglected, as that it has been constrained. It is, for example, much easier to get money for an individual study of a particular phenomenon than to assemble funding of the magnitude essential to any kind of whole-lake or multilake study. Yet, such studies are the key to providing the knowledge and understanding called for by the International Joint Commission. The achievement of a better balance between the many human needs in the Great Lakes region, and the capacity of its natural resources to satisfy those needs must be based on a thorough understanding of each of the lakes as a system, and of all the lakes together as a larger system. It was this realization that led to the International Field Year for the Great Lakes.

Chapter II

THE INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

"Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more science than a heap of stones is a house."

J. H. Poincaré, 1903.

THE INTERNATIONAL HYDROLOGICAL DECADE

Water has historically been a source of both life and problems to mankind. Wars have been fought over the rights to a supply of this life-giving substance. The introduction of irrigation in the arid bottom lands of Mesopotamia may have been the key to the development of what we call "civilization". Certainly the earth would not support its present population if only the natural distribution of water existed.

Recognizing this key role of water, and the great difficulty of providing enough of it for all the members of our expanding world population, UNESCO, in 1961, sought the help of the scientific community. The UNESCO Executive Board, acting on an initiative by the United States, adopted a resolution drawing attention to the importance of hydrology in world affairs. As a result, a "Preparatory Meeting of Experts in the Field of Scientific Hydrology" was convened in Paris in 1963 to discuss the potential content of an international program in hydrology. The meeting was attended by 96 scientists representing eight international non-governmental organizations, six United Nations family organizations, and 48 nations. Subsequently, their report was circulated to the 112 member states of UNESCO, as well as to other international agencies and scientific organizations, for review and comment. An intergovernmental conference to consider the report took place in 1964, attended by about 150 representatives from 38 countries, five U.N. agencies, and 11 scientific organizations. This meeting endorsed the creation of the International Hydrological Decade - a program of national water resource studies to be conducted by nations cooperating through a Coordinating Council established under UNESCO.

U.N. family agencies involved in the IHD, in addition to UNESCO, include the Food and Agriculture Organization (FAO), International Atomic Energy Agency (IAEA), World Health Organization (WHO), and the World Meteorological Organization (WMO). As in the case of the 106 participating countries, each agency is responsible for its own part of the program.

The official opening date for the IHD was January 1, 1965; the Decade will end on December 31, 1974 - except for some lingering report-writing operations. Many of the functions of the IHD, however, will be continued through a successor program, the International Hydrological Program.

The aims of the IHD are manifold, but they can be summed up in three basic intentions: (a) to strengthen the scientific base for water use and conservation, (b) to stimulate education and training in hydrology, and (c) to improve the ability of both developed and developing nations to cope with their own water problems. To accomplish this, the IHD attempts to foster international cooperation both through U.N. agencies and, more important, through national coordinating committees that are directly in contact with each other. One central stipulation for the approval of any project for inclusion in the IHD program is that the data and information generated must be made available to all - scientists and nations - for study, examination, and analysis. Thus, both the aims and the mechanism of the IHD were tailor-made for the advancement of a bi-national cooperative program such as had been envisioned by Great Lakes scientists for nearly a decade.

IFYGL CONCEPT

It remained only for David V. Anderson, a professor at the University of Toronto who has long been active in Great Lakes Studies, to formally suggest the value of a Canadian/United States cooperative study of the physical hydrology of the Great Lakes in a letter (Appendix E) to the Canadian National Committee for the IHD. On September 17, 1965, the Canadian Committee wrote the U.S. Committee suggesting formal discussion of the proposal. An ad hoc group of representatives of the two Committees (Appendix B) then met in Urbana, Illinois on November 11 and 12, 1965 and recommended establishment of an international Steering Committee to study the idea further and make concrete suggestions. This was done, and the Steering Committee's resulting recommendation that the International Field Year for the Great Lakes be undertaken was approved by the two National Committees for the IHD.

Approval of the new program was based on the realization that, although much important and high quality research is and has been conducted on the Great Lakes and their basins, some of the problems are so large and so complicated that their effective solution can only be approached through a commensurately large, concentrated, and well-coordinated scientific study. It seemed clear that, to be successful, such an undertaking would require not only all the resources and manpower that could be brought to bear from the Great Lakes scientific community, but could make good use of assistance from elsewhere as well.

Moreover, the potential results of a synoptic, comprehensive program such as IFYGL planners envisaged would almost surely considerably exceed the sum of the individual contributions. By conducting the many studies in concert, each could benefit from the facilities available to the others, and from the availability of the data collected for the others.

Many potential benefits could be cited for the new program. Among them were the increased understanding of such scientifically and economically important physical phenomena as:

1) Variations of lake level as related to precipitation, evaporation, and surface and groundwater supplies.
2) The relative accuracy and utility of various methods of measuring evaporation.
3) The modification of climate by large water masses.
4) The formation and dissipation of ice.

5) The movement of water, including its circulation, diffusion properties, and waves (both surface and internal).

6) The physical factors affecting the chemical, biological, and materials balance of a large body of water (including consideration of eutrophication, pollution, and sedimentation).

In addition, major benefits were expected from the use of the lake as a model ocean for the study of air-water interface problems of global importance to oceanographers and meteorologists. Fundamental studies of the exchange of heat, humidity, and momentum (mechanical energy) were expected to contribute substantially to such world-wide projects as the Global Atmospheric Research Program (GARP) and the World Weather Watch (WWW).

PRACTICAL CONSIDERATIONS

Side by side with concern for the scientific problems associated with the Great Lakes was concern for the practical problems facing those with day-to-day managerial responsibilities in regulating the lakes or adjusting to their effect on economic enterprises.

It is generally recognized - if not always fully subscribed to in practice - that a base of fundamental science provides the most practical approach to management of natural resources. However, those who have attempted to address the management of the Great Lakes in the past have regularly encountered the problem the proverbial blind men had with the elephant: descriptions of the parts were available, but there was no way of reliably assembling them into a description of the whole elephant, or the whole lakes system. Fragmentation of responsibility, jurisdiction, and science itself has perpetuated this state of affairs.

IFYGL, however, has been fortunate in that the concept evolved into practice as a scientific program, largely escaping this fragmentation. Field Year planners essentially asked themselves just one fundamental question: "What are the gaps in knowledge of the Great Lakes and how can they best be filled?" Members of the Scientific Advisory Working Groups that were formed early in the planning stages were asked to, and did, work as scientists and specifically not as representatives of mission-oriented agencies or jurisdictional entities (be they nations, provinces, states, cities, or universities). Later, as members of the subsequent Scientific Program Panels, they resumed their institutional "hats" in developing operational plans to support the scientific program.

In their deliberations, it became clear that what was most needed was connective tissue, understanding of the interrelationships of natural phenomena on a lake-wide, synoptic ("whole-elephant") scale. Developing this overall understanding was the mission of no agency, jurisdiction, or institution, but became the central theme of the International Field Year for the Great Lakes. Because of this approach, divorcing the definition of the program from human organizations and focusing upon the natural world instead, IFYGL was able to unite two nations, eight states, and one province, and some 44 government agencies, 20 universities, and a number of other groups and individuals in the pursuit of a common goal - a fundamental understanding of the functioning of the Great Lakes System.

This approach also facilitated the participation of the many and varied organizations. Rather than have to justify the entire program in terms of their own missions, these agencies were free to take on just that part of the overall IFYGL program most suited to their interests and capabilities.

However, as Poincaré observed, it is one thing to accumulate data and another to put it into usable, practical form. IFYGL data was expected to support Great Lakes water resource management in two distinct ways: (1) directly, in analyzed form, as the means of answering present-day questions; and (2) more generally, in a variety of forms, as the source of answers to questions that may be generated in the future, and, in some cases, as the source of those questions. (It is, for example, axiomatic among scientists that to find the right answer, one must first ask the right question).

IFYGL planners and managers were acutely aware of the need for immediately useful information on Lake Ontario. Particularly, information has been needed to support actions taken under the Agreement on Great Lakes Water Quality between Canada and the United States, signed on April 15, 1972. This Agreement assigns greatly increased responsibility to the International Joint Commission for, among other things:

> "(a) Collation, analysis and dissemination of data and information supplied by the Parties (the U.S. and Canada) and State and Provincial Governments relating to the quality of the boundary waters of the Great Lakes System and to pollution that enters the boundary waters from tributary waters;"

As the problems and the needs of Great Lakes water management were identified, the IFYGL scientific program was developed to provide data and information to serve the needs of four user groups:

a) The scientific community - (knowledge and understanding)

b) Water quantity managers - (support of navigation, hydroelectric power, water supply, shoreline management)

c) Water quality managers - (in support of public water supplies, recreation, fisheries productivity)

d) Management of other environmentally-sensitive operations - (lake effects (as through weather, etc.) on navigation, air and ground transportation, operation of shoreline facilities, recreation)

At the end of field operations, the Steering Committee surveyed the applicability of the then apparent results of the Field Year to current practical problems on the lakes. Members of the committee were asked to write down lists of problems and key them to the IFYGL programs that seemed likely to provide solutions. The resulting lists were collated, edited, and circulated to interested parties as a check on whether IFYGL was meeting its goals. The final "master list", with the addition of a key to major management areas, is presented in Table 3.

TABLE 3

POTENTIAL APPLICATIONS OF IFYGL PROGRAMS

Areas of Management: Regional Planning	Water Supply	Pollution Control	Navigation	Power Supply	Recreation	Agriculture	Aquaculture	Land Transport/beach erosion	Management Problems	IFYGL Programs: Terrestrial Water Balance	Water Movement	Energy Balance	Lake Met. and Evaporation	Atm. Boundary Layer	Biology and Chemistry
x									Policy Formulation on Water Diversions	x					
x									Establish seasonal changes in susceptibility of the lake to ecological damage		x	x			x
x									Extreme weather emergencies—development of contingency plans	x			x	x	
x									Development and verification of mathematical models of basin	x	x	x	x	x	x
x	x	x							Groundwater management for supply and waste disposal	x					x
x		x							Sewage treatment plants—location, size, and design		x				x
x		x							Identify nature and location of toxic chemical discharges (for control purposes)		x				x
x		x		x					Location, size, and design of nuclear power plants; policy on waste heat	x	x	x	x	x	x
x			x						Winter navigation—development of policy and operations through improved weather and ice forecasts			x	x		
x			x						Harbor improvements, placement and design of coastal structures, regulation of dredging and dumping	x	x				x
x					x				Location of recreational facilities, beaches, ski areas (snow), fishing, boating . . .		x		x		x
	x								Water supply plant design, location of intakes		x		x		x
		x							Outfall location and design—sewage, waste heat, etc.		x		x	x	x
		x							Management of nutrient inputs to lake from basins; relative importance of sources						x
		x							Baseline information, 4-5 years after IJC survey, to assess rates of change of water quality, and to establish urgency of control programs			x			x
			x						Services to shipping and boating: improved weather forecasts, selection of best courses, aid to ship and boat design, port location . . .	x	x	x	x	x	x
			x	x	x			x	Control and/or management of lake levels	x					
						x		x	Erosion control	x	x				
							x		Management and development of fisheries		x	x			x
							x		Management of present fish stocks, guidance on introduction of new species and re-introduction of depleted native species, control of pests (e.g.: lamprey), development of fish sampling techniques			x			x
								x	Snow and ice removal services			x	x		

DEVELOPMENT OF IFYGL POLICY AND OBJECTIVES

The IFYGL Steering Committee held its first meeting in Toronto on August 9, 1966. In keeping with its bi-national character (four members each from the U.S. and Canada at that time), Co-chairmen were elected: T. L. Richards of the Canadian Atmospheric Environment Service, and W. J. Drescher of the U.S. Geological Survey.

To obtain a "grass roots" reaction to the idea of IFYGL, the Steering Committee organized a Workshop Seminar that was held in Toronto on January 25, 1967, and was attended by seventy scientists active in Great Lakes research. They endorsed the Field Year concept, and made a number of suggestions, one of which was that a formal statement of objectives should be issued by the Steering Committee. This was done, and the statement reads, in part:

> "It is proposed to investigate in depth, through an integrated and fully coordinated group of research programs, a number of basic unsolved, or only partially solved, physical problems associated with the hydrology, meteorology, physical limnology and geology of one of the Great Lakes and its drainage basin. In brief, these programs although fundamental in nature, will seek to improve man's knowledge of the available fresh water supply for such widely diverse purposes as domestic and industrial usages, navigation, power, recreation and sewage disposal. In connection with the last named, studies will be directed at obtaining a better understanding of the physical factors which affect the dispersal of pollutants in the lake."

The policy decision to concentrate on the physical processes of Lake Ontario and its basin was taken deliberately and with full recognition of the immediate importance of ecological and pollution problems. The Steering Committee felt that a detailed understanding of the physical processes in Lake Ontario and its basin was basic to any understanding of its chemical, biological, and nutrient cycles. In addition, the committee recognized that it would have its hands full just planning for the physical studies. In the hope that chemists and biologists would recognize the potential benefits of conducting their studies in concert with those of IFYGL, the committee suggested some options for ancillary or auxiliary programs. These programs would be neither planned nor implemented by the IFYGL, but room would be found for their operations whenever feasible.

Having made this decision, the Steering Committee then decided to organize the entire undertaking under four component programs: Terrestrial Water Balance; Energy Balance; Water Movements; and Atmospheric Water Balance (later renamed Lake Meteorology and Evaporation so as to provide an umbrella for a number of meteorological studies including an Atmospheric Water Balance Project).

In mid-1971, the Atmospheric Boundary Layer Program was split off from the Lake Meteorology Program as a separate study to deal with short-term, high-intensity studies of the air-water interface. Eventually, a Biology-Chemistry Program was formed as a major component through the growing interest of scientists in both countries. (Two new members were then added to the Steering Committee - which was otherwise composed of physical scientists - to reflect this new facet of the IFYGL Program.)

A third policy decision was that the basic tasks within each of the program headings would be the responsibility of those public agencies of the two nations that were already involved in major observational and research programs on the Great Lakes. In addition, universities, research institutes, and individual scientists from all countries were to be invited to conduct studies and investigations in support of the "core" programs (the original four areas), or in related areas as ancillary studies.

Finally, in the development of the scientific program and, later, in carrying it out, every effort was to be made to:

a) Improve the time-density and space-density of standard observations with the goal of obtaining an unimpeachable background of standard data.
b) Replicate the measurement of each parameter by as many methods as feasible to refine our knowledge of the capabilities of the available methods.
c) Develop and/or utilize new methods, and test these against an exceptionally good background of standard observations and data.

In selecting an area of operations, the Steering Committee felt that the study should be concentrated on just one lake, with the expectation that many of the findings would prove valid not only for the other lakes of the Great Lakes system, but also for many of the large lakes of the world. Lake Ontario and its drainage basin was designated as the area to be studied unless pre-Field Year feasibility studies indicated otherwise.

The other lakes were eliminated for a variety of reasons: Erie is atypical because its depth is less than half that of any other Great Lake and it is already grossly polluted; Superior, which would be the best lake from a purely hydrological standpoint, is too remote, making logistical support of operations there unnecessarily difficult; Michigan is entirely within the United States (although covered by the Boundary Waters Treaty) and is hydraulically tied to Lake Huron, making a system that is too complex for an initial experimental study such as IFYGL (Figure 5).

Of all the Great Lakes, Ontario has the simplest form - a steep-sided deep basin that reaches to a maximum depth of 244m (802 ft) near its eastern end. Although it is deep, Lake Ontario has the smallest surface area of the Great Lakes, 19,600 km^2 (7,550 mi^2). Like the other lakes, its land drainage basin is small - about 70,000 km^2 (27,300 mi^2) - in relation to the lake surface area. The lake's level varies through an average annual cycle of 0.55 m (1.8 ft), with a low in December or January and a high in June. The overall range of stage (mean monthly levels) recorded in more than 113 years is 2 m (6.6 ft). Rain fall on the lake averages about 86.4 cm (34 in) annually, while evaporation has been estimated at from 67.6 to 86.9 cm (26.6 to 34.2 in). (Figure 6)

The surface circulation appears to be basically a counterclockwise pattern, predominantly eastward along the southern shore (New York State), and westward along the northern shore (Ontario). Summer thermal stratification appears to insulate the deep bulk of the water from major heat input. In severe winters, Ontario develops a maximum 25 percent ice cover (Figure 7), though it is usually much less (8 percent in a mild winter and about 15 percent

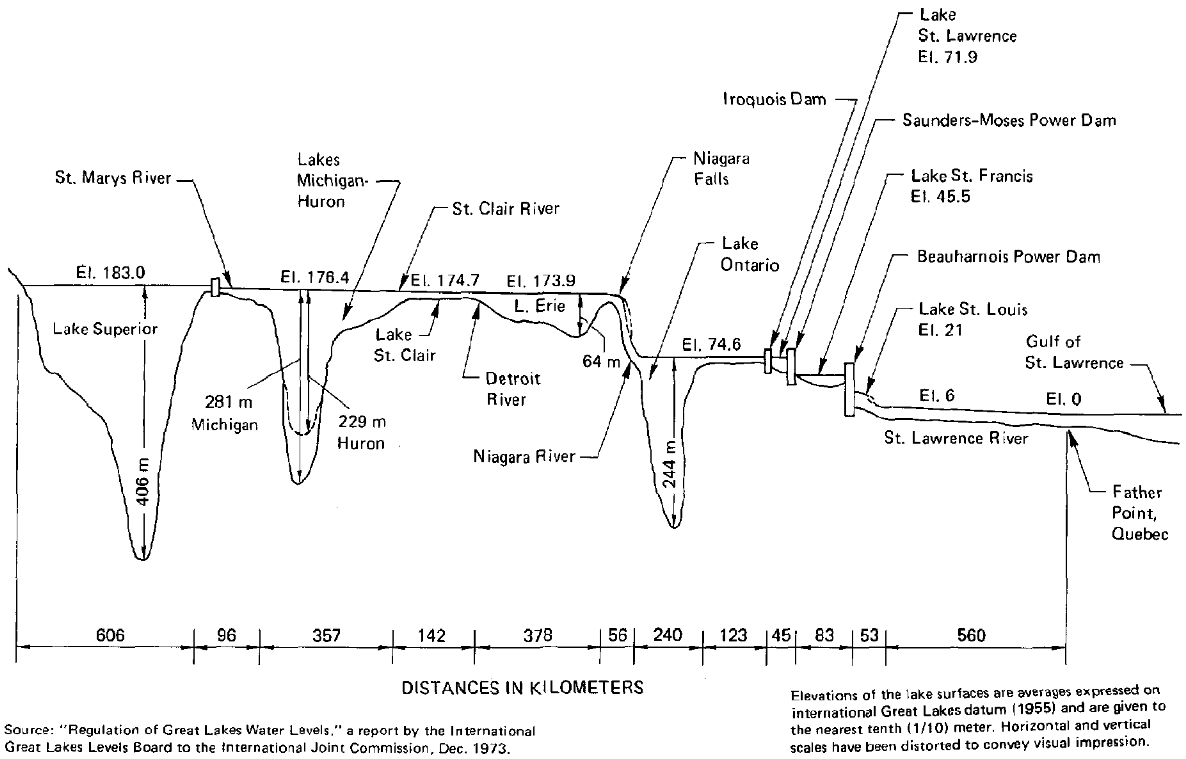

Figure 5. Profile of the Great Lakes - St. Lawrence River System.

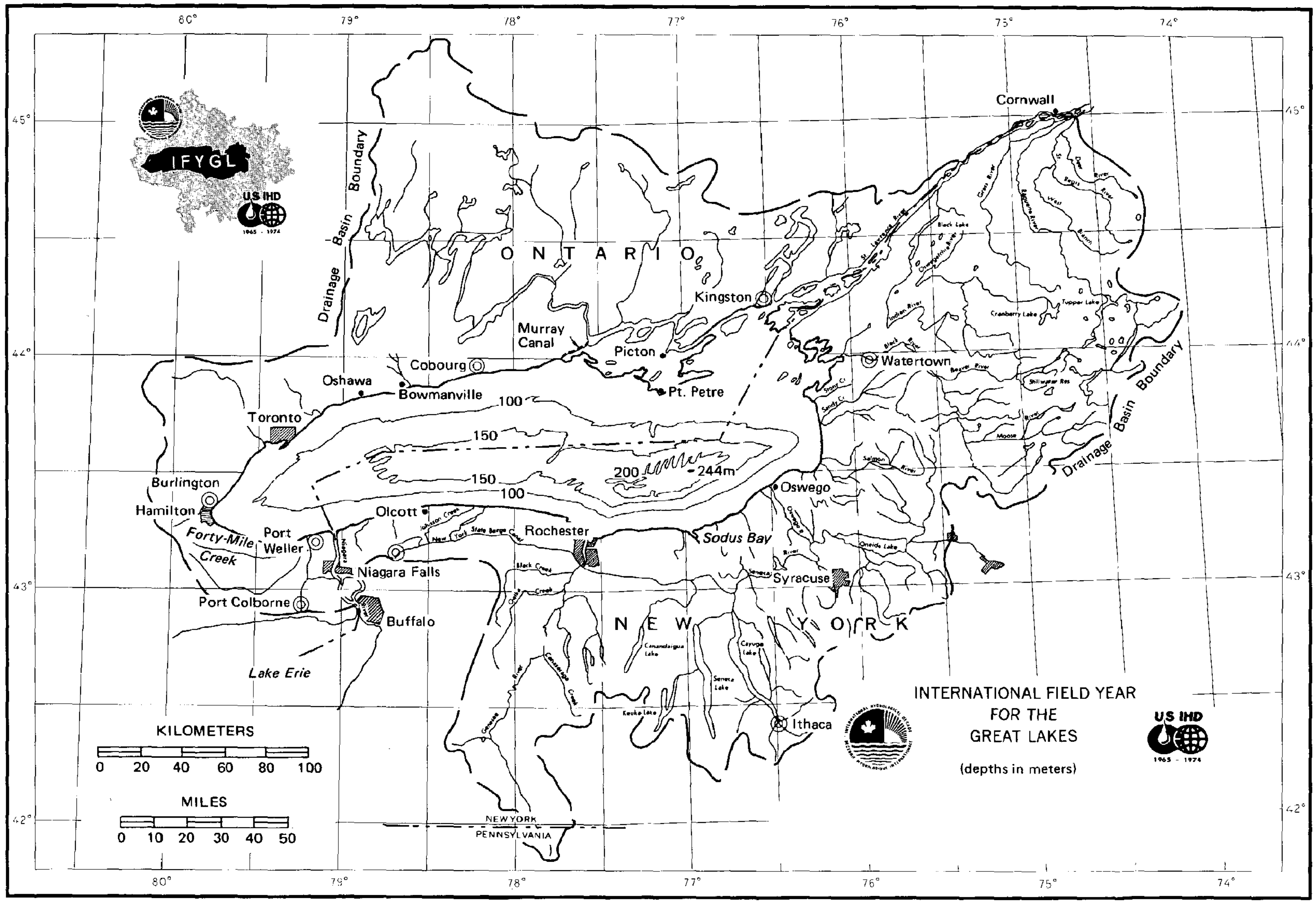

Figure 6. Lake Ontario and its drainage basin.

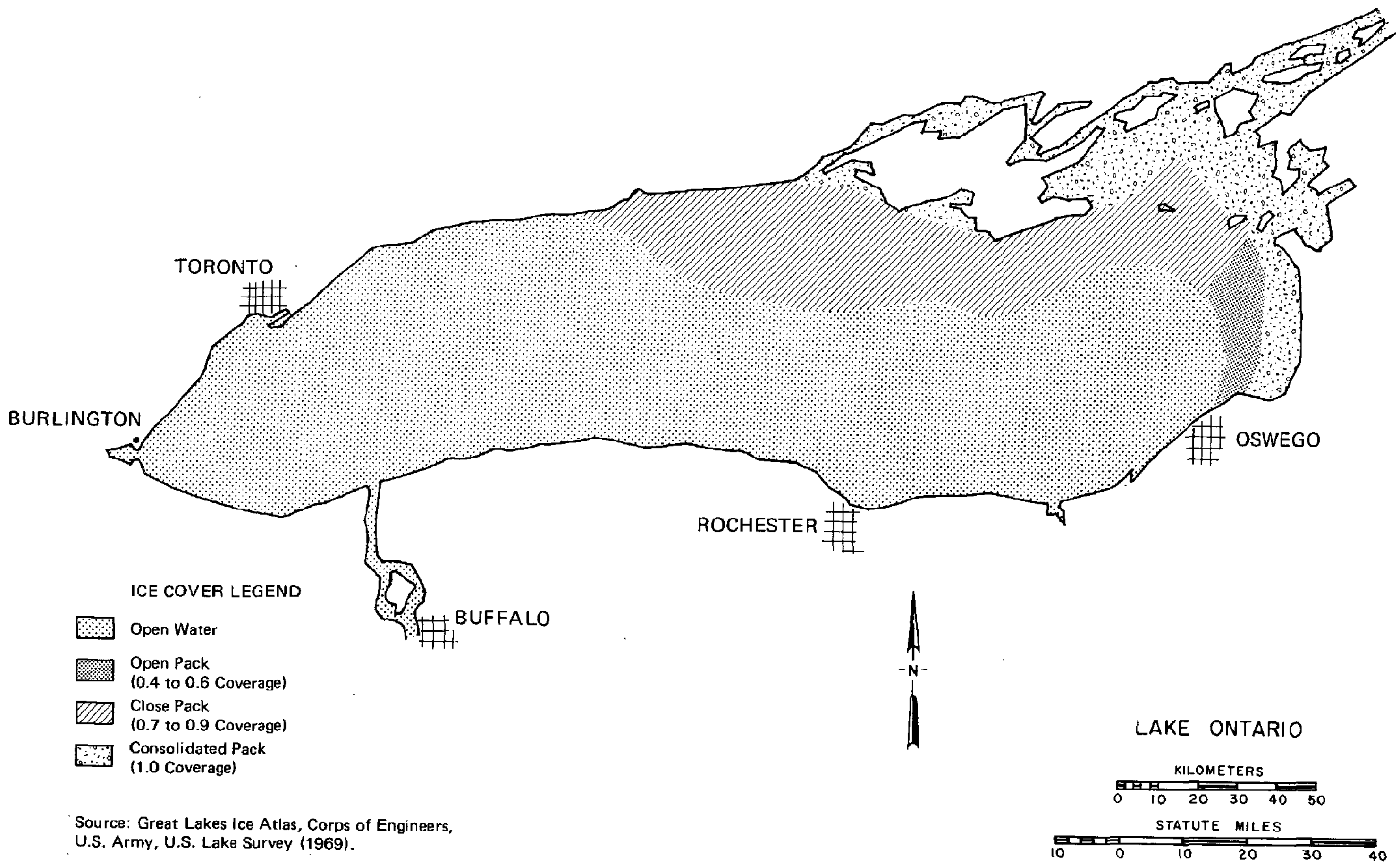

Figure 7. Maximum ice cover on Lake Ontario in a severe winter. (from: Great Lakes Ice Atlas, Corps of Engineers, U.S. Army, U.S. Lake Survey, 1969)

on the average). Like the other Great Lakes, Lake Ontario is dimictic, exhibiting both summer (strong) and winter (weak) stratification, and spring and fall overturns with associated isothermal periods. The lake also has, at varying seasons, conditions of strong shore-parallel currents - the "coastal jet" - and a shore-parallel, vertical thermocline - the "thermal bar" - that, for periods of a few weeks, prevents mixing of near-shore water with that of the central lake (an important consideration, for example, in the design of sewage outfalls).

Lake Ontario had one other great advantage for the Field Year: its accessibility. Ocean-based research ships (two participated in IFYGL) could reach it conveniently through the St. Lawrence Seaway, and vessels from the upper lakes through the Welland Canal. It is also the site, at its western end, of the new Canada Centre for Inland Waters - a multi-million-dollar scientific laboratory and ship facility complex that combines research and administrative functions from a number of federal agencies.

The Steering Committee also proposed a schedule for the IFYGL Program, a timetable that was modified several times before planning and funding were adequate.

Proposed Schedule - IFYGL

1967 - 1968	Planning - feasibility studies - design of projects - development of instrumentation
1969	Instrument and personnel procurement
1970 - 1971	The FIELD YEAR (of 18 months) - April 1, 1970 to September 30, 1971
1971 - 1972	Analyses, tests of results on other lakes

Actually, the planning, instrument and personnel procurement, and feasibility studies continued until April 1, 1972, when a shortened (to 12 months) Field Year began. The delay was due primarily to the difficulty of obtaining sufficient funding and to a last-minute change of agencies responsible for administering and coordinating the program in the United States.

Once basic IFYGL policy had been outlined, and approved, the U.S. and Canadian National Committees for the IHD asked the Steering Committee to proceed with more detailed scientific and financial planning.

To assist in assembling the working groups, advisors, and other personnel, in coordinating the many suggestions for the scientific program, and in securing the necessary financial support, the Steering Committee recognized a need for a full-time bi-national staff. Unfortunately, no simple way to create a single staff was found, and accordingly, two IFYGL Coordinators were appointed, one each in Canada and the U.S.A. The two men originally appointed were S. J. Bolsenga, of the U.S. Lake Survey in Detroit, and Joseph MacDowall, who established his office - the "Canadian IFYGL Centre" - at the Canada Centre for Inland Waters. Later, as a result of a change in the U.S. lead agency, C. J. Callahan replaced Bolsenga as U.S. Coordinator. As field operations came to an end in the spring of 1973, MacDowall was succeeded as Canadian Coordinator by John Sandilands, who was in turn succeeded by Brian J. O'Donnell that fall.

SCIENTIFIC PROGRAM PLANNING

In order to carry out the scientific planning for the Field Year, the Steering Committee organized four Scientific Advisory Working Groups - one for each of the four original component programs (Appendix B). The Committee reserved for itself the responsibility for integrating the final component programs into a single overall whole, thus fulfilling a major IFYGL objective.

The working groups were composed of recognized experts active in their particular fields who were chosen without regard to affiliation or country. In providing advice to the Steering Committee, each member was asked to act solely as a scientist rather than as a representative of his particular organization. Response from the scientific community was most gratifying and membership lists read like a "Who's Who" in the many scientific disciplines concerned with Great Lakes research.

The initial work of the working groups included the identification of the most urgent and important of the many scientific problems on the Great Lakes, and the specification of the study programs and facilities required to solve these problems. There was also an immediate requirement for feasibility studies to ensure that proper methods and techniques would be available for the Field Year programs. The working groups identified the necessary feasibility studies and later evaluated the technical suitability of the research studies that were proposed.

Once the scientific areas and problems to be addressed in the Field Year had been identified, a request for proposals was distributed among the U.S. scientific community (in Canada this was not necessary). In response, the Steering Committee was all but overwhelmed with proposals from government agencies, universities, and the private sector. These proposals were given priority ratings based on their scientific content, relevance to the overall program, and cost-benefit factors; then, areas of overlap among them or gaps remaining relative to the overall program were identified. Finally (in 1968), the Committee, through the principal participating public agencies, began to negotiate contracts with university and private groups on the basis of suggested priorities and as permitted by the availability of funds.

With the initial four areas of the scientific program delineated, and the feasibility of the studies ensured, the Scientific Advisory Working Groups had completed their principal functions. The Biology and Chemistry program that was officially added to the IFYGL Program in October, 1970 was entirely designed by a new group of participants who were expert in those fields. Because of the shortness of time, this program was designed and executed by the same group, designated from its inception as an IFYGL panel rather than as a working group. (The Atmospheric Boundary Layer Program had already been considered by the Lake Meteorology Working Group before it was established as a separate program.)

At this point, the central task facing the Steering Committee changed from the establishment of the scientific program to the development of a detailed plan of action to carry it out. Specifically, the needs were: first, to pull together the data needs of the various tasks into one overall list of data requirements; second, to develop operational plans (specifying facilities, schedules, etc.) for gathering that data, managing its flow, and analyzing it; and, third, to secure the funding and establish an organizational structure to carry out the plan.

The Steering Committee began by selecting a task force - panel organiational structure. With the advice of the Scientific Advisory Working Groups, a relatively large number of specific tasks, or unit research projects (Appendix A), had been identified (eventually, a total of 67 in Canada and 76 in the U.S.), which, taken together, made up the six component programs of the Field Year. Each task then became the responsibility of a task force composed of representatives of those agencies, and academic and private contractors, committed to the completion of the particular task.

These task forces were then grouped into Scientific Program Panels (Appendix B) representing the six final component programs: Terrestrial Water Balance, Energy Balance, Lake Meteorology and Evaporation, Water Movement, Biology-Chemistry, and Atmospheric Boundary Layer. Some task forces were represented on two or more panels to ensure a complete coordination of their efforts. The panels had United States and Canadian co-chairmen who served as advisers to the Steering Committee and the management team that was formed. In that way, and through the three more workshops that were held, the panels played a large role in meeting the first and second needs identified by the Steering Committee. This arrangement proved to be generally satisfactory, and was maintained throughout the Field Year as a means of facilitating information flow and coordination.

At the same time, and later as needs developed, a number of support groups were established. These, typically, dealt on a rather informal basis with specific problems, such as ship operations, data management, procurement and installation of a precision navigation system, public information, and official IFYGL publications.

FINANCE AND MANAGEMENT

One other major area of vital importance confronted the Steering Committee - finance. This proved to be relatively straightforward in Canada, but in the United States the funding of the Field Year was a problem of sufficient magnitude to delay operations for two years, to greatly telescope the time available for preparation, and to influence greatly the management structure that evolved. In the end, however, the total cost of $35 million was shared roughly equally between the two nations.

In Canada, a number of the tasks were selected from among those already in progress. Others came from a re-direction or amplification of on-going Great Lakes studies. Since most of these were carried on by federal and provincial government agencies, or were funded through them, the channels for funding and managing Field Year operations were already available. In most cases, IFYGL tasks were supported through the re-programming of funds; where this was inadequate, agency administrators sought augmentation of their budgets from the Treasury Board. Canadian problems were also considerably simplified by the presence of the Canada Centre for Inland Waters - a large, magnificently-equipped laboratory and ship docking and supply facility - at the western end of Lake Ontario where it served as the Canadian operations center. In addition, three major Canadian research ships were already permanently based on the Great Lakes.

Because of this existing structure, Field Year operations in Canada were managed through the various existing institutions, utilizing their established lines of communication, responsibility, and authority. However, special IFYGL arrangements (such as the support groups) were employed whenever necessary. The focal point of Canadian operations was the office of the Canadian IFYGL Coordinator, located at CCIW. This Canadian IFYGL Centre functioned as a center of coordination and liaison, rather than as a center of direction of operations. The entire Canadian program was overseen by the members of the Canadian half of the IFYGL Steering Committee, all of whom hold managerial positions in the participating institutions.

In the United States, the various research proposals were almost all for new projects that would not have been undertaken or that would have been of much lesser scope, had it not been for the opportunity offered by IFYGL. Moreover, many of the projects proposed were large-scale undertakings, requiring the use of large ships for long periods, as well as other expensive scientific facilities, few of which existed on the U.S. side of Lake Ontario. Even with the economies inherent in the multiple use of the facilities proposed for IFYGL, it was clear that the program required the spending of large amounts of money not previously available.

This difficult funding situation was taken on by the U.S. Army Corps of Engineers as IFYGL lead agency. Through the Lake Survey District office in Detroit, the Engineers submitted proposed budgets for IFYGL in 1968 and 1969 and were rebuffed. However, the Corps was able to partially support an IFYGL Coordinator through this period by reprogramming funds. During this trying period, the Canadian participants agreed to a one-year delay in the original Field Year schedule to accommodate the developments in the United States.

Finally, for fiscal year 1970, the Corps of Engineers was granted a budget of $200,000 to get things started. For the next year, the Engineers were told (by the Bureau of the Budget - now the Office of Management and the Budget) they could apply for more - $500,000 (which they got). With the U.S. program assured of funding, it became obvious that still more time would be needed for preparation, and so, at a Steering Committee meeting in Toronto in late January, 1970, it was agreed that the period of intensive field data collection would be shortened to 12 months, and would now begin on January 1, 1972. While that subsequently had to be further delayed to April 1, 1972, it was the last major readjustment that was made.

In the meantime, the U.S. Congress had been considering the creation of a new national agency devoted to the physical study of the natural aquatic and atmospheric environment. On October 3, 1970 that agency came into being as the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce. Incorporated within the new agency was the Lake Survey, including its Great Lakes Research Center, from the Corps of Engineers. With it came responsibility for IFYGL as U.S. lead agency. shortly after the transfer was completed, NOAA formed an IFYGL Project Office to manage U.S. operations and named Eugene J. Aubert, a veteran of other large programs, to head it.

At this point, it became apparent that an international management structure would be needed to deal with the enlarged administrative tasks then beginning to confront the Steering Committee. Accordingly, in October 1971, a Joint Management Team (JMT) was designated to complement and be responsible to the IFYGL Steering Committee.

The JMT is composed entirely of representatives of the principal agencies having direct responsibility for the expenditure of funds for the Field Year. In Canada, the members of the Steering Committee fitted this description; in the U.S., however, the Steering Committee members, while eminent scientists, were not all agency administrators. As established, then, the Joint Management Team consisted of the Canadian members of the Steering Committee, and representatives of the two principal U.S. funding agencies for IFYGL: NOAA and the Environmental Protection Agency (EPA). The Canadian and U.S. co-chairmen of the JMT were T. L. Richards and E. J. Aubert, respectively. This evolution of the management system into two groups has worked effectively. The Steering Committee makes policy, provides guidance and leadership, and reports to the U.S. and Canadian National Committees for the International Hydrological Decade. The JMT supervises execution of the projects, provides the necessary resources, and reports on progress to the Steering Committee (Figure 8).

Before the start of field operations in April, 1972, three more workshops (in addition to that of January, 1967) were held for participating scientists. The first and second of these were held at McMaster University in Hamilton, Ontario on September 1 and 2, 1970 and July 7 to 9, 1971. They resulted in a considerable advancement in the detailed planning for field operations and, especially in the newly-added area of Biology and Chemistry, in agreement on the final nature of the scientific program. (Figure 9)

The third IFYGL Workshop was held in the facilities of the U.S. National Academy of Sciences, January 18 to 20, 1972. It was followed, on January 20th, by formal public announcement of the impending opening of field operations, at a press conference held in the auditorium of the Academy. A second press conference was held in April at the Canada Centre for Inland Waters to signal the actual commencement of work on Lake Ontario and its basin.

At the January, 1972 Workshop, the U.S. Project Office distributed the first draft of the four-volume IFYGL Technical Plan which it had compiled from material supplied by Canadian and U.S. participants (much of which was developed at the workshops). The four volumes are: I, The Scientific Program; II, The Data Acquisition System; III, The Field Operations Plan; and IV, The Data Management Plan. The Technical Plan was finally issued in loose-leaf binders later that year, and served well as the basis for the subsequent field operations.

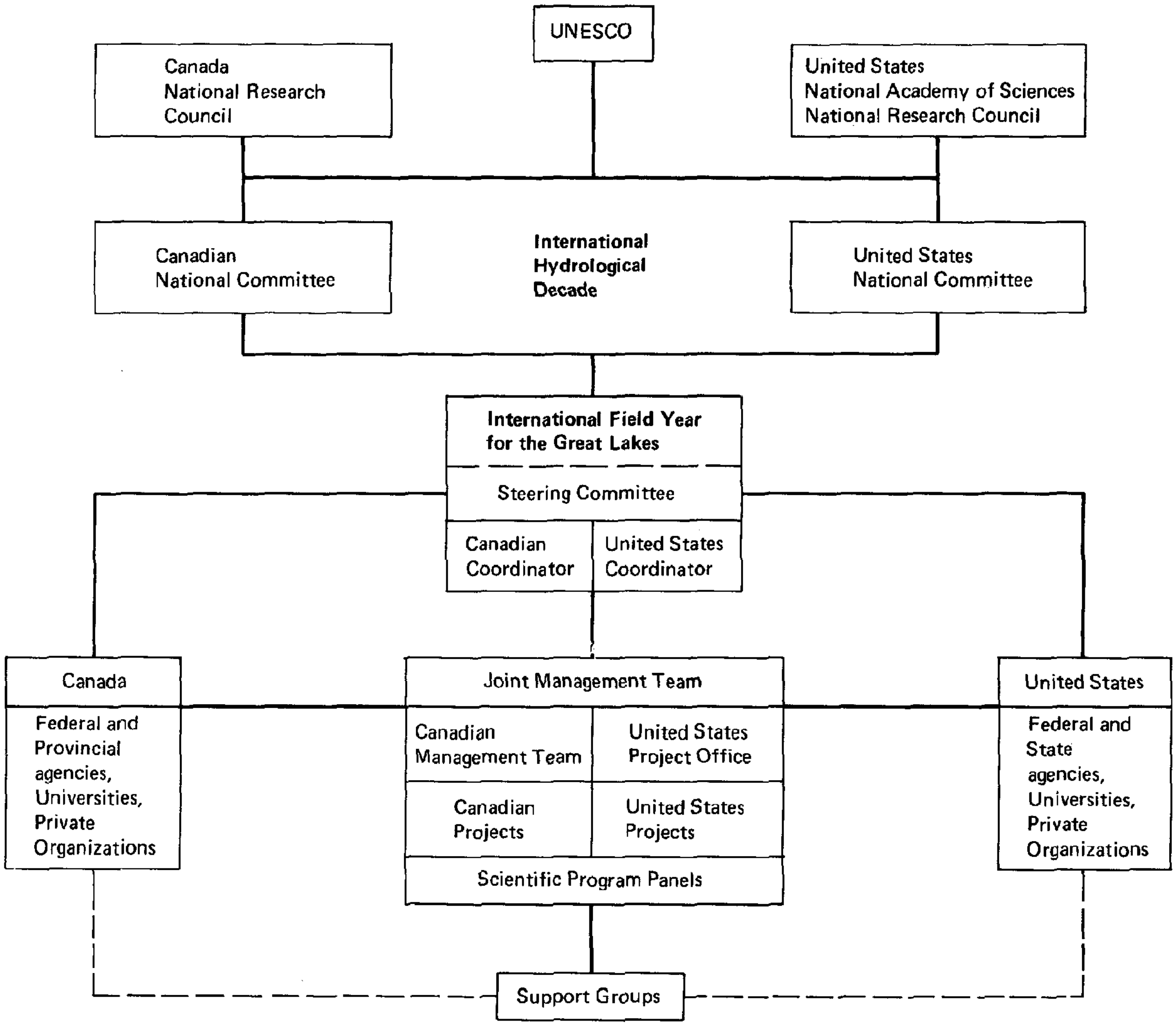

Figure 8. IFYGL coordination chart. The relationships shown are not necessarily those of a rigid organizational hierarchy, but reflect the avenues of communication and coordination employed in the IFYGL. (based on a chart in IFYGL Bulletin No. 1, January 1972)

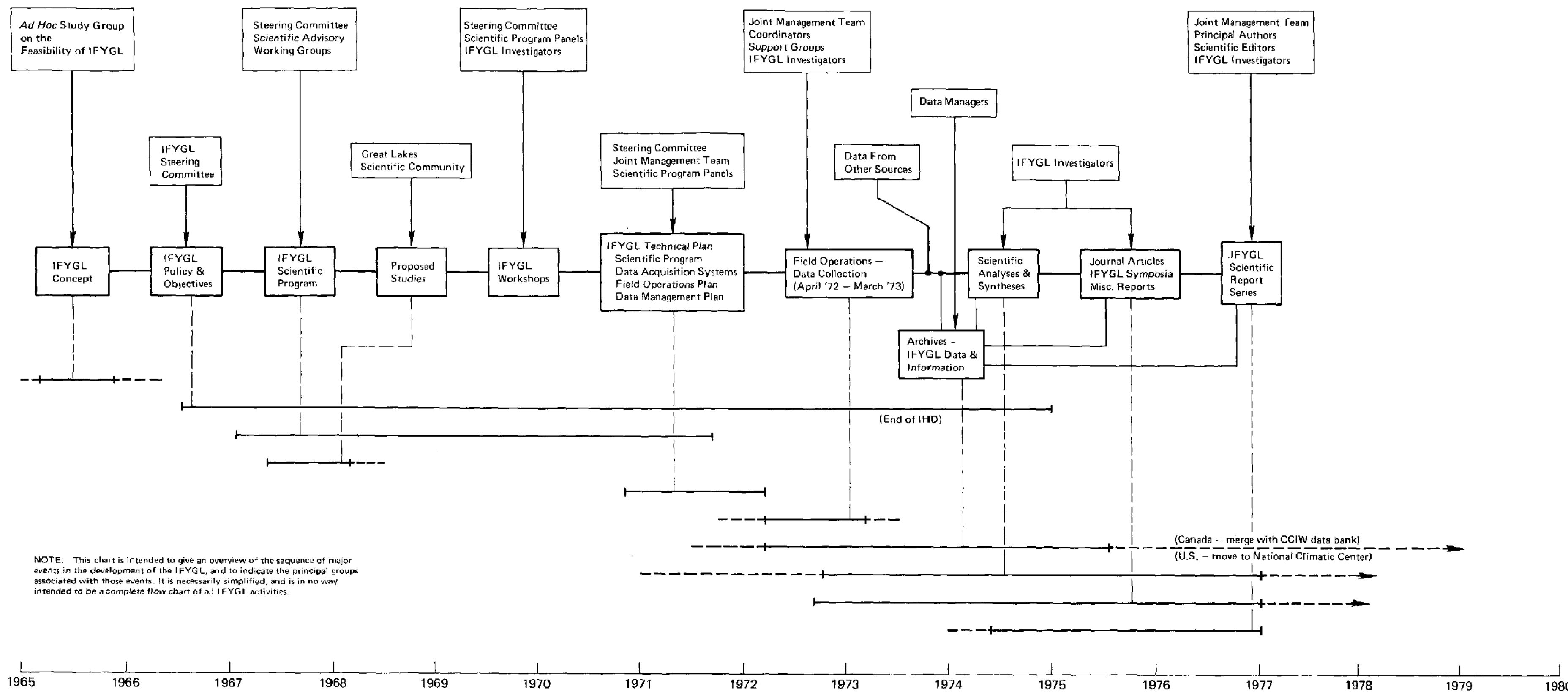

Figure 9. Milestones in the history of the International Field Year for the Great Lakes.

Chapter III

THE SCIENTIFIC PROGRAM

IFYGL was founded on the notion (among others) that the most practical contribution toward effective management of the Great Lakes would be a comprehensive, detailed understanding of the nature of the natural phenomena involved, and of their interrelationships. Happily, achieving such an understanding is a primary scientific goal as well.

By carefully picking the individual scientific tasks, making sure they would complement each other, and then providing for the eventual integration of selected results in various synthesis projects, IFYGL planners hoped to make substantial progress toward that goal. The nature of their approach can best be appreciated through an examination of the six panel programs.

The discussions in this chapter were prepared originally for the IFYGL Technical Plan by the 12 panel chairmen, and have been reviewed and modified by them for presentation here. A complete listing of all the individual tasks that make up these programs can be found in Appendix A; their results-to-date have been reported in the IFYGL Bulletin and in a number of early scientific papers. (For information on accessing and retrieving these reports, see the last section of Chapter V.)

TERRESTRIAL WATER BALANCE

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One means of analyzing the continuous interchange of water among the atmosphere, the land, and the lake in the Lake Ontario basin is the terrestrial water balance. Previous data provide some estimates of the quantities involved. However, in the IFYGL program, the terrestrial water balance in this basin is being studied in greater detail and with greater accuracy than has been previously attempted.

Presently, our knowledge of the lake and land water budget has certain weaknesses. Some of the factors affecting the water balance have been difficult (or very expensive) to measure; for some, few historical records are available. Among factors of which there is little knowledge are evaporation from the lake, and changes in the volume of soil moisture and groundwater storage. Consequently, considerable attention was given to these in preparing and carrying out the water balance program for IFYGL.

In operational terms, the objective of this program has been to investigate and determine, by as many methods as possible, each of the elements of the water balance. Thus, the tasks within the program have been chosen, and organized, so as to provide estimates of each of the factors in the water balance equations for the lake and the land.

Lake equation: $I + P + R_L + G_L - E - O = \Delta S$

Land equation: $P_L - E_L - R_L - G_L = \Delta S_L$

Where:

I = inflow from Niagara River and Welland Canal

P = precipitation on the lake surface

R_L = tributary stream contribution

G_L = groundwater contribution to the lake

E = evaporation from the lake surface

O = outflow through St. Lawrence River

ΔS = change in the lake storage

P_L = precipitation on the land surface

E_L = evaporation from the land surface

ΔS_L = change in land storage

Inflows - Outflows

During the Field Year, measurements were made of the outflows from Lake Ontario through the St. Lawrence River, and of the inflows to the lake through the Welland and Erie Canals, the Niagara River, and the tributary streams in the basin. The direct contribution of groundwater to the lake was determined for both the Ontario and New York sides of the drainage basin using a number of differing techniques.

Lake Ontario receives the major portion of its water supply from the upper lakes through the Niagara River. The inflow has historically remained relatively constant from month to month because the large storage capacity of the upper lakes relative to the flow capacity of the connecting channels smoothes out variations. Nonetheless, there is a noticeable increase in inflow in spring, and a decline in late summer, because of the fluctuation in level of Lake Erie.

Precipitation

Precipitation was measured directly at stations throughout the Lake Ontario Basin, including several stations on islands in the lake. Precipitation rates were investigated by radar observations from sites at Toronto, Buffalo, and Oswego, calibrated with data from networks of standard rain gauges located at Bowmanville, Ontario, and Rochester, New York.

Precipitation on the lake basin is relatively constant for all months of the year, although there is normally a peak in May. Runoff from the land portion of the basin to the lake varies greatly over the course of a year, with values for April averaging (over the 30 years from 1940 to 1969) about ten times those for August. This is largely due to the effects of snow melt in the spring.

Evaporation

Evaporation from the lake surface during the Field Year is being derived from the lake equation, and the results will be compared with the evaporation figures produced in the investigations of other panel programs and those calculated from historical data. Evaporation from the land (evapotranspiration) will be derived using climatological methods, and will be used in the land equation to provide the change in land storage (soil moisture, snow, groundwater storage, and surface water storage).

Some early IFYGL calculations, using figures for evaporation that were derived as a water balance residual element, have shown that by far the most important factors in the water balance are the inflow and the outflow; a one-percent error in either of these terms could result in a 100 percent error in the determination of evaporation as a residual.

Change in Lake Storage

Nineteen water level gauges were operated on Lake Ontario during the Field Year. The records of these gauges are being used to determine the lake level at the beginning and ending of selected periods. The difference between these levels is the change in storage. These records are also used to develop a gauging pattern to obtain end-of-period lake levels.

During the Field Year, preliminary estimates of many of these elements of the water balance have proved to be highly anomalous: maximum inflow occurred in December instead of May; maximum precipitation came in June, normally a month of minimum precipitation; runoff was above normal for all months, and was more than four times the expected value in July.

LAKE METEOROLOGY AND EVAPORATION

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This program consists of a number of tasks designed to investigate specific responses of the atmosphere to the presence of Lake Ontario. The time and space scales of the phenomena studied range from mesoscale to climatological. A good idea of the approach and scope of the scientific plan for this program may be obtained by consideration of its four principal joint projects: (1) Atmospheric Water Balance; (2) Pan Evaporation; (3) Evaporation Synthesis; and (4) Basin Precipitation - Land and Lake.

A number of other tasks are included under the overall IFYGL Lake Meteorology and Evaporation Program; these generally serve to complement the four principal joint projects.

Atmospheric Water Balance

This is the joint scientific project that essentially ties together other joint and individual tasks under this part of the IFYGL Program. Specifically, it is concerned with four objectives:

1) An evaluation of the heat and water balance of the lower and middle troposphere as a function of altitude (or pressure) and time.

2) Estimation of the average evaporation from Lake Ontario for periods of approximately one week, using values of over-lake precipitation from the precipitation radar program, and measurements of the change in moisture content (evaporation less precipitation) of air passing over the lake obtained as a residual from the atmospheric water balance computations.

3) Investigation of the character of synoptic-scale variations in evaporation, and in the heat and water balance of the atmosphere.

4) Investigation of the momentum and kinetic energy budgets of the lower troposphere as a useful auxiliary product of the other computations.

The budget approach outlined in a NOAA Technical Memorandum (ERL BOMAP-3) is the basic means for evaluating the quantities of interest in meeting these objectives. This basic approach has been augmented by using a generalized budget formulation[1/] applicable to the kind of data network used in IFYGL. This generalized budget equation may be written (in short form) as follows:

$$\overline{\frac{dx}{dt}} = - g\frac{\partial \overline{D}_x}{\partial p^*} + \sum_{i=1}^{N} \overline{S}_i$$

[1/] Holland, J. Z., and E. M. Rasmusson, 1973. Measurements of the atmospheric mass, energy and momentum budgets over a 500-km square of tropical ocean. Monthly Weather Review, Vol. 101, No. 1, pp. 44-55.

where:

- x represents the property (such as water vapor, heat, or momentum) for which the budget is required.
- $\overline{(\quad)}$ is a lake area average on a p* surface, where p* is the position on the vertical axis in terms of pressure differential relative to sea level (i.e., p* = 0 at sea level).
- D_x is a generalized vertical diffusion term (for the property, x) which includes the contribution to the vertical flux by all sub-lake-scale eddies as well as the effect of molecular diffusion.
- $\sum_{i=1}^{N} S_i$ is the summation of all source and sink terms appearing in the full length balance equation. Note that in a broader context, these terms may also represent conversion terms, as for example, conversion from liquid water to water vapor or conversion from one form of energy to another.

Pan Evaporation

For this project, the basic data source is a network of six standard Class A evaporation-pan stations - three in Canada and three in the United States. In addition, a U.S. experimental insulated pan, the "X-3", was installed at each station. The U.S. stations were located in conjunction with IFYGL land meteorological stations in order to avoid duplication of observations such as dewpoint and radiation. In Canada, special pan and radiation stations were established at existing manned observation stations so that the equipment would all receive the daily attention required for optimum results.

This observational program has provided the data necessary to compute daily "shallow" lake evaporation values by four essentially independent techniques. (A "shallow" lake is defined as one having low heat storage capacity - a function of depth, and negligible heat advection - the difference in heat content between the inflow and outflow waters.) These values of "shallow" lake evaporation will then be adjusted for heat advection and change in heat storage for Lake Ontario (provided by the Lake Energy Balance Project) to obtain four estimates of Lake Ontario evaporation.

The "X-3" pan serves a dual purpose as an evaporimeter and a radiation integrator. An analysis of the energy budget of the X-3 pan provides estimates of incident-minus-reflected all-wave radiation (Q_{ir}). These Q_{ir} values will provide a check on radiation observations at the meteorological stations to be used in the Energy Balance Program analysis.

While Class A pan operations were discontinued in November because of freezing weather, the X-3 insulated pans were equipped with heaters to prevent freezing and permit winter operation. The amount of heat added was measured and, by analysis of the pan energy budget, values of incident-minus-reflected all-wave radiation (Q_{ir}) were derived for use in computing lake evaporation for the winter months.

Evaporation Synthesis

This project was designed to consider all sources of evaporation estimates to derive "best estimates" of average evaporation for periods of from one to two weeks. Based on these estimates, the mass transfer equation for Lake Ontario was to be calibrated, and estimates of whole lake evaporation based on the shoreline pan measurements were to be made. A strategy for calibration of the mass transfer equation was investigated in a pilot study that evaluated the usefulness of buoy data for the determination of the mean wind speed and mean value of the low level vapor pressure gradient, quantities essential for the calibration. The study indicated that the buoy data will be adequate for this purpose. (Figure 10).

Basin Precipitation - Land and Lake

The aim of this project was to derive measurements of precipitation over Lake Ontario and its basin through the integration of data from the Canadian and two United States weather radars, with that from the special rain gauge networks at Rochester, New York, and Bowmanville, Ontario, a raindrop size measuring instrument (distrometer) at Bowmanville, and from 200 Canadian and 138 U.S. standard rain and snow gauges in the Lake Ontario basin. A special network of 13 precipitation gauges and snow observers from five contiguous school districts was established in the "snow belt" northeast, east, and east-southeast of the Oswego radar site as a means of obtaining direct measurements of snowfall with which to calibrate the echoes received by that radar.

Weather radar played an important role in support of the Terrestrial Water Balance, Energy Balance, and Atmospheric Boundary Layer Programs, and the Atmospheric Water Balance Project by providing needed data from which to estimate precipitation over data-sparse areas (such as Lake Ontario itself), as well as providing the detailed data resolution in time and space that is required to study the effect the lake has on precipitation processes.

Specifically, the Basin Precipitation Project was expected to meet seven objectives:

1) In support of the Terrestrial Water Balance Program, derive bi-weekly totals of the precipitation over the lake and over the basin.

2) In support of the Atmospheric Water Balance Project, provide (a) estimates of the liquid and solid water fluxes from Lake Ontario, (b) precipitation totals over the lake for the intensive periods during the fall season, and (c) estimates of the precipitation type.

3) In support of the Energy Balance Program, provide daily estimates of precipitation totals over the lake, and the precipitation type.

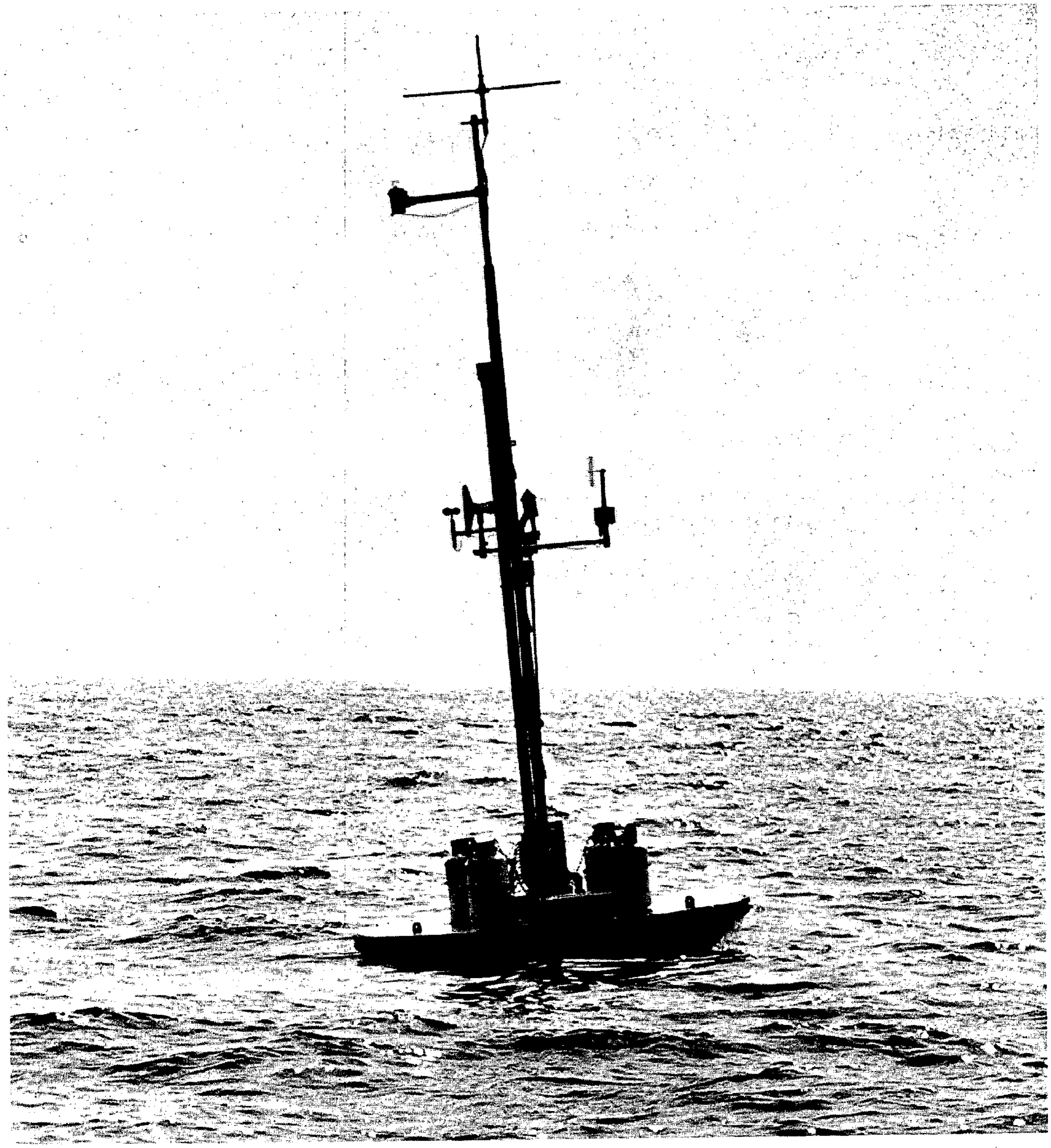

Figure 10. One of the combination meteorological/limnological buoys in the U.S. Physical Data Collection System (PDCS). The four propane tanks on deck supply fuel for the thermoelectric generator inside the hull. (photo by John Ludwigson)

4) In support of the Cloud Analysis Task of the Energy Balance Program, provide digitized displays in map form of the echo intensity field over the lake and basin at approximately three-hour time intervals.

5) In support of the Atmospheric Boundary Layer Program and the Synoptic Studies Task of the Lake Meteorology and Evaporation Program, provide digitized displays of the echo intensity fields at 10-15 minute time intervals for several selected "lake effect" storms.

6) Prepare a series of papers describing different storm types observed.

7) Prepare descriptive models of the mesoscale precipitation patterns generated by the lake under various atmospheric conditions and air-water temperature contrasts. These models will be used to derive relationships for estimating over-water precipitation from land precipitation measurements and to help verify mesoscale precipitation patterns predicted by theoretical models.

Radar collection and processing of the magnitude used during IFYGL has not been attempted previously for two basic reasons. First, there had previously been no system for collecting and processing radar information that was both accurate and economical. Second, the relationship between radar echo intensity and rainfall rate shows large variations both within and between storms.

The first difficulty was overcome by utilizing radar processing and recording systems developed by the U.S. National Severe Storms Laboratory and by the Canadian and United States weather services. The second difficulty was minimized by using rain gauge measurements to adjust the radar estimates. The technique utilized for combining the radar and gauge data is similar to that described by Wilson[1/]. The basic rationale behind the approach is that the radar has the capability of measuring relative differences in precipitation from place to place but lacks accuracy in measuring the absolute magnitude. Thus, rain gauges were used to adjust the storm-to-storm variations in the radar reflectivity-rainfall rate relationship and for large within-storm variations in the relationship. In determining the weight to be given a particular gauge for calibration purposes, the following were considered: the gauge-measured precipitation, the spatial rainfall variability about the gauge, the distance and direction of the gauge from the radar, and the distance of the gauge from the area to be adjusted.

1/ Wilson, J., 1971. Use of Rain Gauges to Adjust Radar Estimates of Rainfall. The Center for the Environment and Man, Inc., Final Report CEM 4098-448.

LAKE ENERGY BALANCE

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The energy exchange between atmosphere and lake is a fundamental factor in understanding the climatic effect of a water body on the atmosphere and the surrounding land area and, conversely, of the effect of the atmosphere on the water body itself. In addition, energy supply is the basic input for some mathematical models of lakes. This factor varies in both time and space. Despite the significance of energy exchange, however, few data have been available for a water body the size of Lake Ontario, and calculations of the total energy exchange are based on empirical equations and inadequate over-lake data.

The measurement of the heat content of the lake and its time-spatial variation is of major interest, since the heat flow affects the climate, and thus the ecology of the lake and its basin, as well as the formation, growth, and decay of lake ice. The radiation balance is a major component of the energy exchange, strongly influencing the heat content of the lake. As an example of the climatic effect, the heat stored in the lake affects the length of the growing season in areas close to the lake shores, and therefore, affects the agricultural potential in the basin. Some typical values for the components of heat exchange and heat content changes are given in Table 4.

The results of this program will provide data to better understand weather characteristics both on the lake and the land, and to improve forecasting of ice formation and decay on the lakes, evaporation from the lakes, the water balance, lake weather conditions and disposition of both natural heat input and that introduced by human activity (such as an electric generating plant).

Specifically, the objectives of the Energy Balance Program are to:

1) Define the general and specific properties of the energy budget of a large dimictic[1/] lake.

2) Evaluate all the terms of the energy balance equation for the entire lake, and for multiple segments comprising the total area. This objective, while concerned specifically with Lake Ontario in 1972, will also be considered in the general sense as it may apply to the energy budget of any large dimictic lake.

1/ (i.e., a lake with two yearly "overturns" or periods of thorough neutral mixing such as a freshwater lake in a temperate climate with overturns in the spring and fall.)

Table 4

LAKE ONTARIO ENERGY FACTORS

Range of mean monthly values* (Rodgers and Anderson, 1961).

Incident Solar Energy	+95 to +550	gmcal	$cm^{-2}day^{-1}$
Reflected Solar Energy	+10 to + 35	"	"
Heat Stored in the Lake	-510 to +505	"	"
Longwave Radiation from Lake	620 to 820	"	"
Longwave Radiation from Atmosphere	525 to 720	"	"
Evaporation	-35 to +240	"	"
Net Advection	-12 to + 2	"	"
Sensible Heat Transfer	-95 to +260	"	"

*Based on 10-year mean monthly meteorological data for the period of 1950-1960, and ship observations in the period of 1958-1961.

3) Provide an estimate of evaporation as a residual of the energy balance equation, and compare this estimate with evaporation estimates obtained by other techniques, such as those used in the Terrestrial Water Balance and Lake Meteorology and Evaporation Programs.

4) Determine the changes in the density stratification within the lake that result from seasonal changes in the transfer of heat and mechanical energy across the lake surface.

5) Study the growth and decay of ice, the types of ice, and the effect of ice on the exchange of heat between the lake and the atmosphere.

In the most general of energy balance studies two types of energy transfer to the lake may be considered. Energy of motion can be imparted by flows through the lake (river inflow and outflow) or by momentum transfer across the air-water interface. The ultimate frictional disposition of these motions generates negligible water temperature changes in comparison with such heating sources as solar radiation. Thus, one can deal with overall lake heating without concerning oneself with the details of kinetic energy in the lake.

In considering the heat content of some portion of the lake, or considering the temperature response of the lake (heat redistribution), both energy components are interdependent.

Water motions are being studied in detail under another Panel program; the basic whole-lake heat balance is being studied within the Lake Energy Balance Panel together with the temperature distribution in the lake. When it comes to investigation of the re-distribution of heat within the lake, this study will link with the water movements study.

Turning then to the specific part of the study called the 'heat balance,' we may consider an equation of the following form:

$$Q_s - Q_r + Q_a - Q_w - Q_h - Q_e + Q_v - Q_t = 0$$

Where:

Q_s = incident solar radiation

Q_r = reflected solar radiation

Q_a = long wave radiation from the atmosphere

Q_w = long wave back radiation (from the lake surface)

Q_h = sensible heat transfer

Q_e = evaporation

Q_v = advected heat

Q_t = heat content change

In this equation, chemical and biological, geothermal, and radioactive decay processes are not considered significant in serving as heat sources.

Incident solar radiation (Q_s) - This includes radiation in wavelengths up to 4μm from sun and sky. Because cloud cover over a lake is significantly different from that observed at land stations, direct measurements of solar radiation must be made from ships or instrument towers on the lake, and from islands or shoreline promontories. Since solar radiation is a large term in the balance equation, every effort was made to ensure high accuracy in measurement of this parameter, and to supplement radiation measurements with cloud cover observations.

Reflected solar radiation (Q_r) - Empirical equations will be used to calculate this term, given Q_s and the solar angle and cloud cover. Some direct measurements were made to check the equations and to establish whether sea state has an important effect on overall light reflection.

Long wave radiation ($>$4μm) from the atmosphere (Q_a) - Semi-empirical equations for calculating this parameter are available, but they have not been tested in this latitude (roughly, 43° 30' N). Essentially, these equations are the products of two factors: the first, a Stefan-Boltzmann expression for temperatures of the air near the lake surface; and the second, a factor depending on cloud cover, cloud height, and water vapor content of the atmosphere. Direct measurement of this radiation, or this radiation in combination with Q_s, has been carried out at a number of sites. Data from these, in combination with the above-mentioned equations will be used to estimate this term.

Long wave radiation from the lake surface (Q_w) - This term can be measured directly, although such measurements are not common. The term can also be calculated from the lake surface skin temperature; values of surface water emissivity for the radiation were determined in studies carried out in preparation for the Field Year.

Sensible heat transfer (Q_h) - The objective of working on a heat balance, apart from understanding the relative magnitude of the various terms, includes deriving an estimate of evaporation consistent with the heat balance. The procedure will be to derive an expression for the sum ($Q_e + Q_h$) from estimates of all other terms for the periods between ship surveys, and then aportion this sum utilizing the Bowen Ratio (Q_h/Q_e). The Bowen Ratio, expressing the relative magnitudes of Q_h and Q_e as a function of temperature and water vapor concentration gradients, assumes similitude in the transfer mechanisms for heat and water vapor. One can anticipate that several techniques for combining meteorological data to produce this ratio will be attempted. Some special experiments in which standard meteorological data, buoy meteorological data, and actual measurements of these fluxes, are obtained simultaneously may shed light on the validity of the assumptions implicit in this approach.

Evaporation (Q_e) - Evaporation will be taken as the unknown in the heat balance equation. Estimates so derived will be compared with estimates of evaporation derived from other techniques. Since a part of the procedure in solving for evaporation in this equation involves assumptions about the evaporative process, this method of obtaining evaporation estimates is dependent upon the same data being used for mass transfer estimates. Further details are found above in the discussion of sensible heat transfer (Q_h). It should also be noted that condensation, rather than evaporation, will be the dominant process in some of the spring months.

Advective heat exchange (Q_v) - This factor may be important for heat budget studies in the Great Lakes. The most significant areas for examination of advective heat exchange are at those points of inflow and outflow that are considered critical to water balance estimates, but cultural inputs of heat (e.g., power plants) also need to be evaluated, and are included in this term for convenience. Temperatures were monitored continuously on the Niagara and St. Lawrence Rivers, and on several other major rivers draining into Lake Ontario. These data, combined with the flow volumes of the rivers, provide the natural advective heat transfer to or from the lake. It should be noted that the heat balance equation must be consistent with the water balance equation, though it turns out that the heat balance equation is not particularly sensitive to the accuracy of the water balance determination, when considering periods of two weeks or greater.

Heat content change (Q_t) - Temperature profiles to determine the heat content of the lake were obtained by various types of vessel surveys, and from the network of buoys.

Ice and snow - During the winter, it is essential to collect data on the albedo ($r = Q_r/Q_s$), which, with a snow cover, significantly modifies the net radiation exchange. Assessment of the lake heat content (Q_t) requires estimates of the rate of formation or melting of ice.

The approach to the overall Energy Balance Program in Lake Ontario is divided for convenience into several units as follows:

1) Radiation terms - net radiation exchange or the sum of Q_s, Q_r, Q_a, and Q_w.

2) Calculation of heat content changes in the lake - derivation of Q_t from ship surveys of lake temperature; estimates of Q_v.

3) Ice and snow studies - studies relating to these topics as units unto themselves and as they affect the heat budget of the lake.

4) Heat balance calculations and evaporation estimates - the compilation of all terms in the heat balance with emphasis on the relative magnitude of the various terms, and on derivation of an evaporation estimate consistent with heat balance.

5) Thermal structure - a basic description of the lake thermal structure observed, and efforts directed toward an explanation of the structure by combining the results of the heat balance study with results from water movement studies.

These five units are presented here in order of the degree of data synthesis they require; the division of the units is somewhat arbitrary.

Some ancillary projects that feed useful data into this core program include remote sensing programs dealing with lake surface temperatures and the transmission of light within the upper layers of the lake.

The total Energy Balance Program draws heavily on several data collection systems established for the Field Year, and especially on data being collected under the auspices of the Atmospheric Boundary Layer, and Lake Meteorology and Evaporation Programs.

WATER MOVEMENTS

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In broad terms, the objectives of the Water Movements Program are to describe and interpret mid-lake and coastal circulation patterns and their interdependent thermal structure, diffusion characteristics, and kinetic energy transfer across the air-water interface through wind stress generation of both currents and surface waves. The characteristics of lake- and coastal-scale water motions are being determined through extensive current measurements from moored buoys in the central lake basin and from small vessels near the coastal boundaries. At the same time, measurements of applied wind stress and of water density distribution provide information regarding the origin and persistence of the forced motions. The products will include a comprehensive data base concerning the natural distribution and variability of physical properties within Lake Ontario, as well as diagnostic and simulation models of mid-lake and coastal circulation and diffusion, and of internal and surface waves.

A detailed knowledge of circulation and diffusion processes is an essential factor in understanding the distribution of physical, chemical, and biological properties in a lake. Thus, it is a prerequisite for water quality modeling studies, for assessing the impact of heated effluents, for lake restoration studies, and for planning the industrial and recreational uses of a lake. Moreover, an increased knowledge of wave climatology will benefit navigation, will improve our capability to predict wind set-ups, surges, and seiches, and will be useful in the design of harbors and structures placed in or on the lake.

The Water Movements Program meshes closely with the Lake Energy Balance and Atmospheric Boundary Layer Programs. In particular, estimates of wind stress from the Boundary Layer Program are a necessary input for circulation and surface wave models.

Tasks to be undertaken in the Water Movements Program were separated into two groups. The first group consists of mid-lake and coastal current studies, including those relating to the interdependent temperature structure. These, primarily synoptic, investigations are lake-wide in nature, requiring international cooperation, and are the basis of the following description.

The second group of tasks includes more specialized studies that were undertaken by individual scientists or agencies. These do not necessarily require international cooperation, and their objectives are sufficiently limited that the research could be reasonably performed independent of the intensive data gathering activities of the International Field Year for the Great Lakes. Interpretation of the results of these investigations will benefit materially, however, from the simultaneous collection of correlative data which, under usual circumstances, is beyond the capabilities of the individual investigator to obtain.

Recent theory, and observations of water movements in large stratified lakes have shown that circulation patterns result from the addition of two main components. Wind stress, and unevenly distributed heating and cooling of surface water drive one main component; the second is driven by the propagation of long internal waves on the density discontinuity (thermocline). Moreover, theory predicts, and observation confirms, the existence of two types of internal waves. Poincaré waves are basin-wide in dimension and cause thermocline oscillations of like magnitude throughout the lake. The undulating topography of the thermocline is associated with extensive and periodic redistributions of water density and the generation of certain oscillatory current flows. Internal Kelvin waves are edge waves that propagate on the thermocline about the perimeter of the lake Basin. They influence thermocline topography and current flows in a coastal strip not exceeding 8 to 10 km in width. The existence of an internal Kelvin wave may be characterized by the occurrence of shore-parallel "coastal jets" of water flow.

The Water Movements Program tends to be split into mid-lake and coastal parts because of the differences in the phenomena characterizing these regions. However, the splitting is not meant to imply that the circulation patterns are independent between regions; indeed, the IFYGL Program provides an opportunity to assess the relationship between the mid-lake and coastal flows.

This relationship, in fact, may be very strong with respect to the decay of energy associated with the mid-lake current flows. The results of some recent work in this area suggest that the energy of these currents may be dissipated primarily through bottom friction along the lake coasts. This factor enhances the importance of the coastal boundary regions in controlling the rate of decay of wind-stress-generated mid-lake currents, and in transferring momentum from the surface water across the thermocline to the deeper water masses. The large excursions of thermocline depth observed near shore as compared with the excursions over the deep lake basins also emphasize the importance of the coastal zone as an active area of water mass mixing and exchange between the upper and lower layers.

Joint U.S.-Canadian projects established in order to study these topics are:

Mid-Lake Circulation (buoy systems)

Water current and temperature measurements sufficient for a lake-wide investigation of spatial and temporal coherency in the velocity and temperature fields were acquired through a mid-lake network of 10 U.S. and eight Canadian buoys. Lagrangian current measurements were also made in mid-lake, using 10 free-drifting drogue buoys. The data obtained has been used to help in the interpretation of measurements made by the fixed buoy network.

Coastal Circulations (coastal chains)

Coastal circulation patterns were delineated through data from three coastal chains on the south shore of Lake Ontario and two chains on the north shore. Each "chain" consisted of from 10 to 30 marker buoys (orange styrofoam blocks) anchored from 1 to 2 km apart in a line extending from shore about 10-16 km. Technicians in small boats measured current speed and direction, and water temperature at selected buoys twice a day during four-week "alert periods" (they also took some meteorological data as a check on other systems). There were three of these "alert periods" during the Field Year, with the observing schedule centered about the ends of the months of May, July, and September. (Figure 11)

Description of Internal Waves

Internal waves are important because of their direct influence on the temperature structure of the lake near shore and therefore, for example, on whether water from above or below the thermocline is drawn into water intakes. As there are considerable differences in both water temperature and chemistry between those fractions of the lake water separated by the thermocline, knowledge of the internal wave climate is essential for planning intake locations for either potable or industrial cooling water. Currents generated by the propagation of long internal waves are a major constituent of measured water motions and they contribute to the advection and dispersal of chemical and biological elements of the lake environment.

The purpose of the field studies was to quantify the internal wave properties. Results of this will be useful not only for description of Lake Ontario, but also for subsequent verification of more general numerical and theoretical lake models. Temperature data was collected on the Rochester-to-Presque Isle, Oswego-to-Prince Edward, and Olcott-to-Oshawa transects in three five-day intervals of continuous ship operations towing a temperature-sensing "fish" back and forth across the lake. Fixed temperature-profiler measurements also were made near three of the Canadian buoys located in the transects.

Figure 11. Recovering the portable current (speed and direction) meter at one of the coastal chain stations in preparation for moving to the next station. (photo by John Ludwigson)

Surface Wind Waves

The immediate objective of this project is to describe the surface wave climate of Lake Ontario. Such a description is required for the design of coastal structures, increasing the safety of navigation, and the mitigation of shore erosion. Long-term objectives include the improvement of forecasts of wind wave generation for the Great Lakes, the determination of wave growth characteristics at limited fetch, and the improvement of design wave statistics for each of the Great Lakes.

Preliminary Synthesis

As a guide to physical modelers and to members of other IFYGL panels who require knowledge of water movements, a qualitative description of the major circulatory features and events observed during 1972 in Lake Ontario is being prepared. The purpose of this description is to provide a summary of gross current features observed during the Field Year for use by those requiring general information, but not necessarily interested in undertaking extensive analyses of the actual current records.

Circulation Modeling

Three investigators are modeling the circulation of Lake Ontario, taking into account the basin geometry, density structure, and driving forces, but using different analytical techniques and assumptions. The models are either numerical or analytical in nature. Most recent lake circulation models have been of the numerical type and the interest of most individuals involved in the IFYGL program is in numerical modeling. The purpose of the modeling effort is readily apparent, as a good circulation model is an essential starting point for any efforts to predict the distribution of the chemical or biological elements of the aquatic environment.

BIOLOGY AND CHEMISTRY

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Problems and Objectives

In general, the goals of the Biology and Chemistry Panel of IFYGL were to develop scientific information for (1) water pollution control management needs, and (2) the development of fisheries resources.

Three areas of study were identified that bear directly on both these problems; in addition, a considerable effort was made to directly study the nature and present extent of the fishery resources of Lake Ontario. The three general areas are:

1) Material balance studies: This involves the evaluation of the relative importance of pollution sources and the identification of sites at which control measures could be effective.

2) Theory of large lake processes (including an assessment of current pollution stresses): This includes the description of the current ecological status, the elucidation of processes, rates, and mechanisms in the lake as required to determine the needs for abatement and management efforts, and monitoring the effectiveness of such efforts.

3) Mathematical modeling and data synthesis: This involves the development of predictive tools (mathematical models) for making management decisions.

Accelerated eutrophication is the most often-cited of the water quality management problems that have been identified in the Great Lakes. Control of this process by limiting the nutrient inputs figures prominently in management plans for Lake Ontario. One objective of the Biology and Chemistry Program has been to provide an accurate, detailed description of the present trophic status of the lake as a baseline against which the success of such management efforts can be assessed. The trophic status of the lake must be defined biologically, as well as chemically, and the intensive sampling of the biota carried on during IFYGL will provide this information for all major taxa, including algae, zooplankton, benthic organisms, and fish. Results of these studies will also be contrasted with measurements of nutrient chemicals made in 1967 under the International Joint Commission (IJC) mandate, to give one measure of the rate of deterioration of the lake.

The fisheries problems of Lake Ontario are of special management concern. Where the open waters once contained valuable stocks of fish such as lake trout, ciscoes, and whitefish, now only smelt and alewives are found in abundance. This has caused severe economic shock to both the commercial and sport fisheries.

Even given control of eutrophication, over-fishing, and the parasitic sea lamprey, all of which were major factors in the decline of the fisheries, management will still face great problems in redeveloping an ecosystem that takes full advantage of the productive potential of Lake Ontario. The attainability of this goal depends heavily on the availability of a good description of the present biota of the lake and an understanding of the interactions among its various elements. The major objectives of the fishery study are, therefore, to determine the relative abundance of the various fish species in the lake, and to measure the seasonal and spatial changes in their distribution. Further investigations are expected to yield a picture of the food webs, and of the vectoring of materials and solar energy in the lake.

In addition, in order to improve the understanding of the transport of deleterious substances such as heavy metals and pesticides through the lake system, samples of all organisms, including fish-eating birds, were collected and are being analyzed.

Determining how much and what kind of sampling will be needed to monitor future changes in the fish stocks was an especially important consideration. In the past, commercial fishermen contributed most of the information on stock changes, but this is no longer true because the fisheries of Lake Ontario now cover only a limited area of the lake, and this with a narrow range of types of gear. Moreover, the fishing gear used for sampling is slow, and the fish themselves are highly mobile and some species school; all of which factors contribute to the difficulty of obtaining consistent and reliable stock appraisals. The problem is of considerable urgency, because a rehabilitation program (control of the parasitic sea lamprey, reintroduction of salmonid fishes) is already underway in Lake Ontario, and a long-term international monitoring program is needed immediately.

Data Collection

The sampling plan for the IFYGL biological survey combined a lake-wide synoptic collection at 60 stations with locally intensive investigations to study such phenomena as short-term distributional changes, vertical movement, and plankton grazing. This work was mainly carried out by the larger Field Year ships. The U.S. part of the program included intensive near-shore investigations of all elements of the biota, and most of the studies of benthic organisms. Studies of the alga *Cladophora*, the phytoplankton, and the zooplankton were shared between U.S. and Canadian investigators. (Figure 12)

In the fisheries area, there was almost continuous sampling in the open water season along both shores where fish density and species diversity are highest. In the open lake, the small vessels *Cottus* and *Kaho* provided broadly synoptic coverage during matched cruise periods. During the intervening cruises *Cottus* carried out mid-water trawling at a single area to examine short-term horizontal and vertical changes in fish distribution, while *Kaho* collected plankton and benthic organisms.

The chemistry part of the program combined lake-wide synoptic collections for water chemistry analysis with interval measurements of chemical inputs from the streams and outputs down the St. Lawrence River. In addition, certain watersheds were singled out for more detailed study of their contributions to the materials loading of the lake.

In planning the data collection for the Biology and Chemistry Program, every effort was made to utilize ship cruises planned for other programs in order to maximize the physical background information available. Sampling targets were largely met. A late start on spring biology and chemistry sampling on the U.S. side, and problems caused by tropical storm Agnes occasioned the extension of the sampling period to the end of June 1973. Similarly, the Canadian fisheries program had a delayed start, and two replacement cruises were undertaken in April and May 1973.

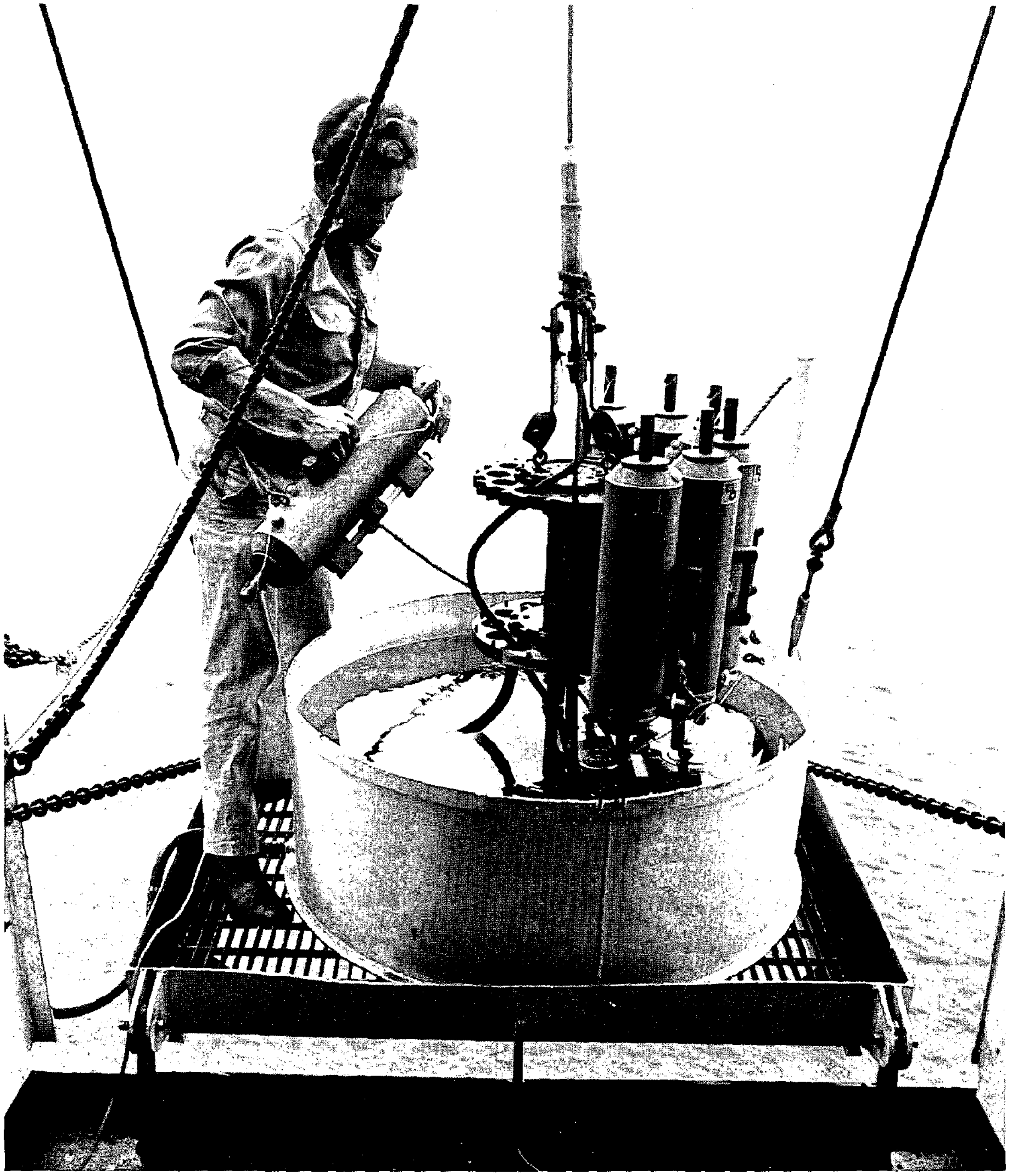

Figure 12. The "Rosette" water sampler used on the U.S. ship Researcher. Each of the 12 bottles collects a water sample from a different depth for both biological and chemical analyses. The device also includes a temperature-vs-depth sensor. (photo from NOAA)

Most of the sampling for the Biology and Chemistry Program was based on known equipment and procedures. However, some developmental procedures were also employed, and these may have significance for future programs. The study of the potential of echo sounders to measure animal biomass, and the use of remote sensing from aircraft to measure Cladophora biomass are noteworthy examples, although others might be cited.

Analysis

Summarization of the biological information will require considerably more time than will be the case with the chemistry data. Four distinct stages in the reporting can be identified for any taxon as follows:

1) Status - species composition, relative abundance distribution

2) Life History, Production, Intra-taxon Relationships - biomass (where applicable) turnover, transport and/or movements, grazing rates (zooplankton), food and feeding, growth rates (fish), fecundity and maturity (fish)

3) Inter-taxon Relationships - food pathways (includes primary productivity and local pollution effects)

4) Generalized Models - models of lake productivity (both local and whole-lake)

Items 2) and 3) are not altogether separate, since feeding studies span various biological groupings. The inputs to 3), however, will to an important extent consist of published works in 1) and 2). Inputs from other panels occur at all three levels and the materials balance data enter at 2) and 3). The fourth level is not so predictable in its products since they depend to an important extent on the success of previous analyses.

ATMOSPHERIC BOUNDARY LAYER

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Introduction

The atmospheric boundary layer is that layer of air which immediately overlies the earth's surface (land, water, snow, ice, etc.) and is directly involved in the exchange of properties with the surface. In the case of the water surface of a lake, it is the layer of air that is modified due to the presence of the open-water surface and that, in turn, influences the lake surface through the transmission or transference of energy or matter. The rate of transfer of a particular form of matter or energy is termed its flux. The flux across the lake/air boundary (or interface) is described as a net gain or loss, to either the air or the water, of the quantity in question.

The fluxes of water mass, heat, and momentum across the lake/air interface are among the most important of the many processes affecting the lake and the climate of the lake basin. They are major influences on the lake water budget, energy budget, and circulation and mixing, as well as on the weather in the basin. Thus, the ability to determine and to predict the quantitative values of these fluxes is an important lake management tool.

The goal of the IFYGL Atmospheric Boundary Layer Program is to develop and to verify parametric means of determining the surface fluxes: i.e., means by which the fluxes can be computed from indirect and simplified measurements. This is necessary because direct measurements are not feasible on an operational basis due to their complexity and consequent expense. Parameterization is developed in the form of mathematical models that relate the fluxes of interest to standard meteorological measurements. Some such models existed prior to IFYGL, but their applicability to a large lake had never been verified.

The Boundary Layer Program, therefore, consists of tasks whose aim is (1) to measure directly the surface fluxes, and (2) to relate these fluxes to other variables through the use of models. This approach was also expected to produce a more detailed understanding of the boundary transfer process, test existing models and evolve new or improved models. The specific objectives of this program were brought together under three main areas of investigation (projects): surface fluxes; boundary layer structure and modes of mesoscale organization; and parameterization (Figure 13)

Determination of Surface Fluxes

The aim of this project is to determine the rates of transfer, between the lake and the atmosphere, of momentum, heat, water vapor, and selected trace substances. The project has been subdivided into four categories with the following objectives:

1) Obtain a set of direct ("primary") measurements of eddy fluxes of momentum, heat, and water vapor at times and locations covering a wide range of ambient conditions, and having sufficient accuracy and spectral bandwidth to serve as a standard of comparison for approximate or indirect ("secondary") methods of measurement or estimation. Five semi-independent methods of measurement were employed in order to permit an evaluation of bias, random error, and the spectral bandwidth limitations of each primary method.

2) Obtain estimates of area averages and spatial distributions of the surface fluxes of momentum, heat, and water vapor over Lake Ontario and its basin. In this case, "secondary" methods were employed that are based on the use of a large number of relatively simple meteorological observations distributed over the area. The applicability of these methods will be validated by intercomparisons with the "primary"

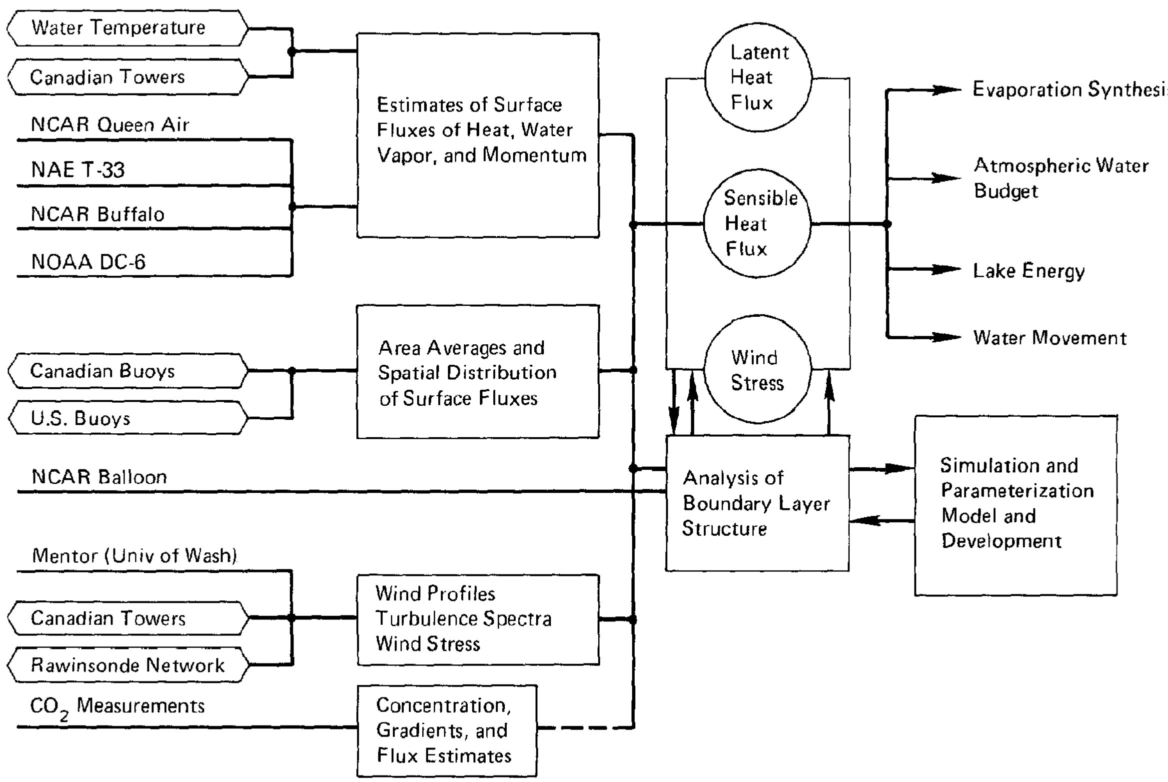

Figure 13. Data flow and organization of the studies in the Atmospheric Boundary Layer Program.

measurements. These area averages were also designed to meet the requirements of the Panels on Lake Meteorology and Evaporation, Terrestrial Water Balance, Energy Balance, and Water Movement.

3) Provide data on wind profiles, atmospheric turbulence spectra, and surface wind stress for the development and testing of wave generation theories and prediction models.

4) Obtain a set of data on the concentrations, concentration gradients, and fluxes of selected trace gases and particulates (pollutants, nutrients, or natural or artificial tracers). Estimates of the flux of selected pollutants or nutrients whose concentrations in water are significantly affected by transfer between the water and the atmosphere have been derived from this data set for use by the Biology and Chemistry Program Materials Balance Project.

Boundary Layer Structure and Modes of Mesoscale Organization

Tasks in this project area were designed to describe (1) the internal structure, and the modes of organized motion and energy transfer that occur in the boundary layer as a result of either surface boundary inhomogeneities or internal dynamic processes; and (2) the response of the internal structure to discontinuities of surface stress and heat flux at the lake shore. In recent years, many models have been proposed relating the response of the atmospheric boundary layer to surface discontinuities of roughness and heat flux, and describing modes of secondary flow such as Kelvin-Helmholtz waves, convection cells and roll vortices that develop as a result of internal mechanical and thermal instabilities. This project and the data collection effort for it were designed to support subsequent numerical simulation and parameterization studies.

During the Field Year, a wide range of physical environmental conditions was available for measurement and study. Seasonally, the following types of boundary surface differences between land and water are encountered along the shorelines of Lake Ontario:

	Land		Lake		Land
May, June	rough warm	to	smooth cool	to	rough warm
August	rough neutral	to	smooth neutral	to	rough neutral
October, November	rough cold	to	smooth warm	to	rough cold

IFYGL has provided an unprecedented opportunity for quantitative study of the effects of these transitions on pressure field, three-dimensional secondary circulations, and turbulence and turbulent flux distributions, and of the resulting distributions of trace gases and aerosols.

Alert periods - i.e., periods when several investigators would combine their measurement efforts - were chosen to encounter each of the lake-land transitions listed above. In addition, encounters with other significant variations in the influences of the lake on the large scale atmospheric processes were expected. When gradient winds are light, the lake-land contrasts tend to develop their own circulation (a lake-land breeze regime was the object of one special study). Under strong gradient winds, the lake may represent only a small perturbation on the general boundary layer flow.

The combining of studies of boundary layer structure, surface flux measurement, and larger-scale modes of energy transfer is designed to serve two primary purposes:

1) To permit non-random phenomena, such as convection cells, to be taken into account in the syntheses of surface flux distributions, area averages, and atmospheric momentum and energy budgets.

2) To test boundary-layer theories, mesoscale flux parameterizations, and mesometeorological simulation models.

Parameterization

The aim in this project area is to test and develop models for parameterizing boundary layer momentum, heat, and water vapor fluxes, and flux divergence in terms of the synoptic or mesoscale observations available from standard meteorological networks, under conditions of the strong mesoscale variation in surface physical characteristics and time variability represented by a lake-land boundary. A set of accurate observational data on all input and output variables of parameterization models in current use was collected, and is being used to test these models. In the process of model testing, improvements are being developed, based on the new information and insight gained from analysis of the experimental data. As a result, it seems likely that more advanced models will be developed or will evolve from the present models.

ANCILLARY AND SUPPORTIVE TASKS

There are six Canadian and two U.S. tasks that do not fit within the foregoing specific program areas.

The six Canadian tasks include: (1) the use of low- and high-altitude infrared (IR) scanner imagery, as well as the ERTS-1 data, to study the principal thermal features of Lake Ontario and their effects on large-scale water circulation; (2) the use of satellites (with good success) such as ERTS-1 and the IRLS (Interrogation, Recording, and Locating Sub-system) system on Nimbus to relay data from one moored and one free-drifting buoy in the Lake; (3) the conduct of a bathymetric survey of the lake; and (4) (5) and (6) three support operations.

The two U.S. tasks utilized the photography and scanner imagery from the ERTS-1 and ITOS-D satellites to assess ice coverage and cloud formations over the lake. In turn, data from other projects and tasks were used to establish "ground truth" for the satellite observations.

Chapter IV

DATA COLLECTION - FACILITIES AND OPERATIONS

Field data collection, which began in April, 1972, was an immensely diverse, multifaceted operation, involving the coordinated operation of a fleet of ships, a lakewide network of research buoys (of several varieties), aircraft, weather radars, precipitation gauges, and a number of specific installations measuring such things as solar radiation, cloud cover, snowfall, and air/water interactions.

This massive assemblage of scientific data-gathering facilities was put together on the basis of the scientific program worked out by the Steering Committee, and by participants in the IFYGL Workshops. In settling on the scientific program, the requirements of the various tasks for data, and the kinds of operations and facilities that would be needed to satisfy those requirements had been identified. The lists of proposed facilities were then assembled, edited to remove redundancies, and presented to the Steering Committee. The various agency heads present were able to tentatively commit nearly all of the required facilities on the spot. Arrangements for the remaining facilities were then made by negotiation, through the Joint Management Team (JMT), with other agencies and organizations.

With the necessary facilities committed to the Field Year, the JMT, working with the program panels and support groups, planned the details of their operation. The results of this effort were then published as volume three of the IFYGL Technical Plan, the Field Operations Plan. With a few exceptions, mostly occasioned by tropical storm Agnes which hit the lake in late June, 1972, this plan was carried out in the field.

The Field Operations Plan was quite detailed, spelling out the sources of the various facilities, giving operational schedules, and describing the particular measurements to be made in terms of such items as location, method of data acquisition, the platform to be employed (e.g., ship, buoy, tower, etc.), timing, and sequence. Difficulties that arose in the field were generally ironed out by direct communications among the personnel involved. For example, when a broken sensor cable threatened operation of the rosette water sampler used aboard the NOAA ship Researcher, the Canada Centre for Inland Waters was able to find an immediate replacement cable in stock, enabling operations to continue with minimum delay.

Preparation of a detailed technical plan also made it possible to avoid in advance most of the difficulties that might have arisen due to the different management arrangements in Canada and the United States. Those responsible for a particular facet of data acquisition were able to operate according to the pre-set schedule, confident that others were doing the same. This arrangement worked very well; the JMT had little work to do in terms of day-to-day supervision of operations.

In addition to this internal organization, the Field Year benefited greatly from the cooperation of many institutions, agencies, and individuals not directly a part of IFYGL. Port authorities, customs services, aviation agencies, private marine facilities, and individual residents in the Lake Ontario basin all proved willing to cooperate in both large and small matters that, collectively, contributed much to the success of the program. (For example, the lone resident of Galloo Island, the site of a land meteorological station, agreed to check the station and change its propane tanks on a regular basis throughout the Field Year.)

Another prime factor in the success of the field operations - one of the reasons Lake Ontario was selected to be studied - was the accessibility of the lake. Particularly on the Canadian side, the basin is home to a number of major Great Lakes research organizations (see Appendix C). On both sides, it is bordered by major cities and towns. Moreover, it is conveniently accessible to ocean-going ships through the St. Lawrence Seaway, and to research vessels based on the other Great Lakes through the Welland Canal.

In Canada, the lakes research organizations included the Canada Centre for Inland Waters (Canadian IFYGL operational headquarters) at Burlington, the headquarters of the Atmospheric Environment Service at Downsview (near Toronto), the Ontario Ministry of the Environment and Ontario Ministry of Natural Resources, and the University of Toronto's Great Lakes Institute (the first major Great Lakes research organization in Canada). Other participating, nearby, Canadian academic institutions included McMaster University in Hamilton, the University of Guelph, and the University of Waterloo.

United States principal Great Lakes research organizations are mostly located outside of the Lake Ontario basin; these include the NOAA Lake Survey Center in Detroit (formerly a part of the U.S. Army Corps of Engineers), the University of Michigan's Great Lakes Research Division at Ann Arbor, and the University of Wisconsin at Milwaukee and Madison. In the Lake Ontario basin, the Environmental Protection Agency (Region II) established, just in time for Field Year operations, a major new water quality laboratory at the University of Rochester. A major responsibility of this laboratory is the assessment of the biological and chemical state of Lake Ontario. The EPA lab served as the center of U.S. Biology Program activity during the Field Year. Participating U.S. academic institutions in or near the lake basin include the State University of New York (SUNY) at Buffalo, Oswego, and Albany, and Cornell University.

DATA COLLECTION SYSTEMS

While data collection operations employed a great variety of platforms and sensing systems, the great bulk of the data gathered for IFYGL was collected through six principal systems. These were the five major ships, the lakewide buoy network, the meteorological radars (and accompanying precipitation gauge networks), the many and varied aircraft, the six-station rawinsonde system, and the shoreline meteorological stations (Tables 5 and 6).

IFYGL Table 5

U.S. MAJOR DATA COLLECTION FACILITIES

Facility		Source Institution
2	major research ships	
	Researcher (85 m)	NOAA/AOML
	Advance II (56 m)	CFTI
3	20-meter Great Lakes research ships	
	Shenehon	NOAA/LSC
	Dambach	State (NY) University College at Buffalo
	"Oswego T-boat"	SUNY/Oswego
1	fisheries research ship	
	Kaho (20 m)	BSFW (DI)
2	support vessels	
	Johnson (catamaran, 17 m)	NOAA/LSC
	Jane E. II (launch, 10 m)	rented by NOAA/IFYGL
1	buoy tender	
	Maple (37 m)	USCG
3	5-meter coastal chain boats	SUNY/Albany
Physical Data Collection System		
	10 meteorological and limnological research buoys	NOAA/IFYGL
	4 instrument towers	NOAA/IFYGL
	1 island station (Galloo Island)	NOAA/IFYGL
	5 land meteorological and data relay stations	NOAA/IFYGL
3	rawinsonde stations (Sept. 15 to Dec. 15, 1972)	NOAA/IFYGL and USAF/AWS
2	weather radars	
	at Oswego (5.2 cm)	SUNY/Oswego
	at Buffalo (10 cm)	NOAA/NWS
11	aircraft	
	RB-57F	NASA
	U-2	NASA
	CV-990	NASA
	DC-6 (39C)	NOAA/RFF
	Buffalo	NCAR
	Queen Air	NCAR

	twin Beech (D-18)	Aerojet-General Corp.
	twin Bonanza	E. G. & G., Inc.
	Aztec C	CAL
	C-47	UM/WRL
	Buffalo	NOAA/NOS
1	helicopter (Bell 204B)	rented by NASA
1	helicopter (transport to Galloo Island)	USCG
38	water wells (gauged & ungauged)	NYSDEC, USGS, private
36	river and stream gauges	USGS
4	satellites	
	Nimbus (IRLS)	NOAA/NESS
	ERTS-1	NOAA/NESS
	NOAA-2	NOAA/NESS
	DAPP	USAF
138	precipitation gauges	NOAA/NWS, LSC, IFYGL

IFYGL — Table 6

CANADIAN MAJOR DATA COLLECTION FACILITIES

	Facility	Source Institution
3	major research ships	
	CCGS Porte Dauphine (38 m)	AES/CCIW/Univ. of Toronto
	CSS Limnos (45 m)	MSD/CCIW
	M/V Martin Karlsen (67 m)	MSD/CCIW
1	buoy tender (20 m) and small launches	MSD/CCIW
3	fisheries research ships	
	Cottus (14 m)	OMNR
	Keenosay (17 m)	OMNR
	Namaycush (13 m)	OMNR
11	meteorological buoys	CCIW
9	current-measuring buoys	CCIW
4	temperature profiler buoys (moored at current-measuring stations)	CCIW
3	deep-water (Bedford) towers with profile-measuring equipment	AES

3	micro-meteorological towers with barge and small launch	CCIW
3	land stations for Decca position-fixing system and shipboard equipment	MSD/CCIW
6	automated shoreline meteorological stations	AES
3	rawinsonde stations	AES
1	radar station (C-band, 5.2 cm) and computer data integrator	AES
6	aircraft	
	Cessna 310	CCIW
	Aztec C	AES
	T-33	NRCC/NAE
	Falcon (fanjet transport)	CCRS/ASU
	Dakota (C-46)	CCRS/ASU
	Piper Comanche	rented by CCIW
-	meteorological networks	AES
34	water wells (gauged)	OME
161	water wells (ungauged)	
-	selected soil moisture sites, snow courses, and water quality stations	OME
-	river and stream gauges	Water Survey of Canada
200	precipitation gauges	AES

The major ships were the Researcher and Advance II from the U.S., and Martin Karlsen, Limnos, and Porte Dauphine from Canada. Each of these ships was fitted with a basic data acquisition system, as well as additional equipment appropriate to the purposes of the particular cruise. The various kinds of cruises, usually lasting about a week each, included lakewide temperature surveys, water sampling surveys, and temperature transects in which two or three ships would steam back and forth across the lake along single tracks for a week at a time, towing submerged temperature profiling sensors. (Figures 14, 15, & 16)

The U.S. ships were fitted with a specially-designed shipboard data system that automatically recorded radiation, water surface temperature, air temperature, wind speed and direction, and humidity, as well as subsurface data and navigation information. The Researcher was also equipped with a

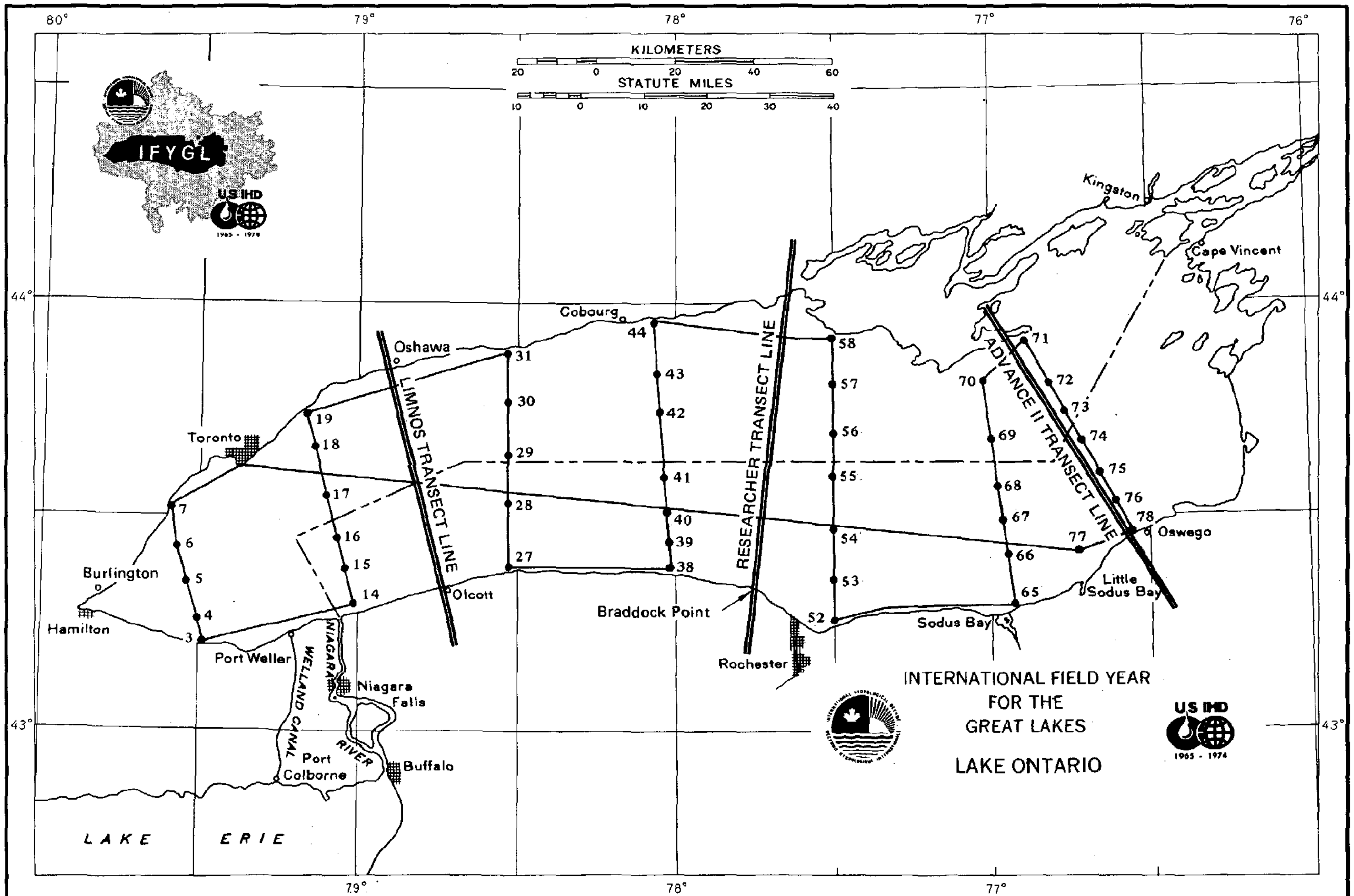

Figure 14. A sample ship track (numbered lines) for half of a temperature survey cruise (by the Porte Dauphine, based at Toronto), and the temperature transect lines along which the ships named steamed continuously for a week at a time.

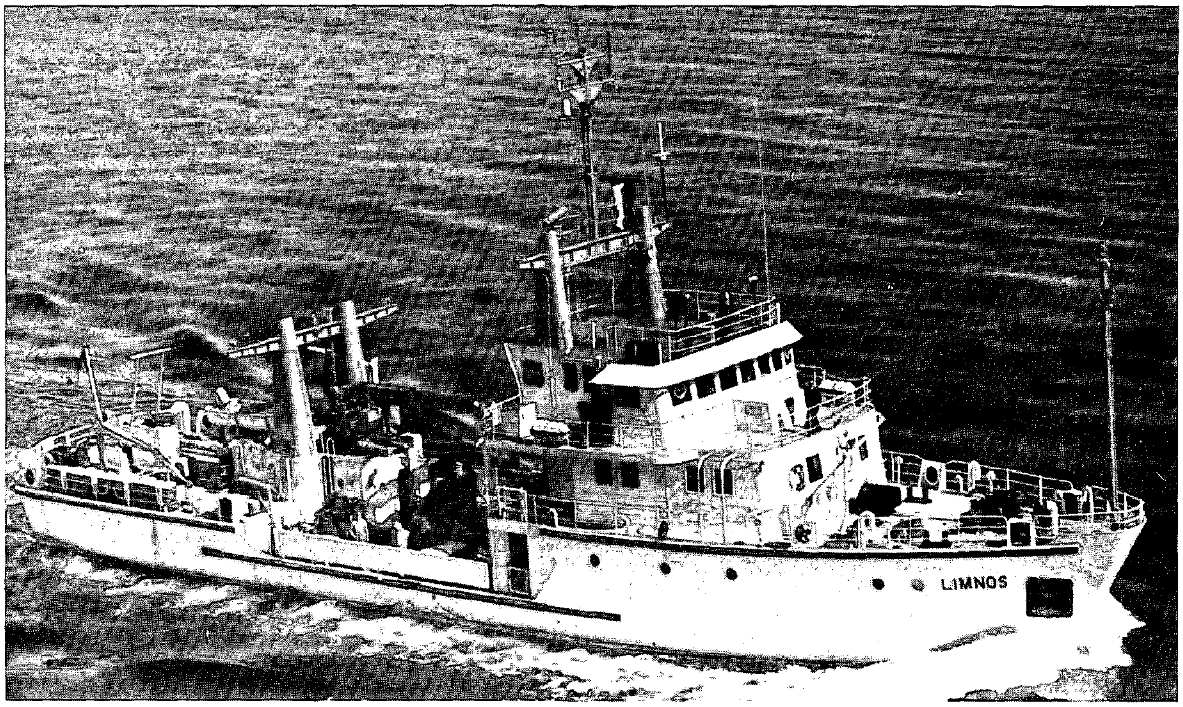

Figure 15. CSS Limnos, the only ship in the program designed and built specifically for Great Lakes research work. Limnos, and the Martin Karlsen (a larger, ice-strengthened ship), are based at the Canada Centre for Inland Waters, Burlington, Ontario. (photo from CCIW)

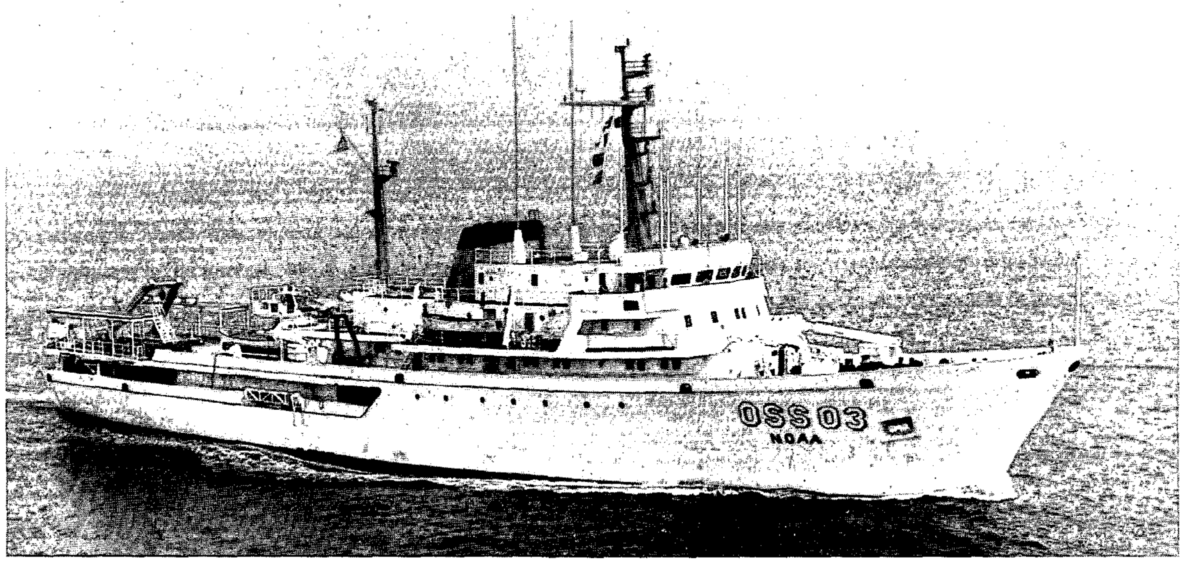

Figure 16. The NOAA ship Researcher, usually based at the NOAA Atlantic Oceanographic and Meteorological Laboratory in Miami, Florida. (photo from NOAA)

Rosette-type sampler for collecting multiple samples of water at different depths, and was capable of determining some chemical concentrations in an on-board laboratory. Both ships carried electrobathythermographs (EBT's) for profiling temperature from the surface to the bottom, as well as separate towed temperature sensors for continuous measurement of water surface temperatures.

The Canadian ships Martin Karlsen and Limnos carried data acquisition systems that recorded surface water temperature, hull water temperature (just below the surface at one of the ship's intake pipes), air temperature and relative humidity, global solar radiation, and infrared radiation (between 3 and 50 μm). In addition, these ships also carried EBT's and towed temperature profilers. The Porte Dauphine carried many of these sensors, and participated in a variety of cruises, including those to determine surface chlorophyll content, and water transparency and color.

Ships and boats on both sides of the lake also carried out comprehensive fish and benthic fauna surveys (Figure 17), conducted near-shore and harbor circulation studies, and regularly profiled current speed and direction, and water temperature along the five "coastal chains". The coastal chains consisted of a series of small buoys, set out about 1 to 2 km apart in a line perpendicular to the shoreline to mark the stations at which these measurements were to be made. The chains typically extended out up to 16 kilometers into the lake, ending at deep-water buoys.

A total of 21 principal buoy-mooring sites were established over the lake (Figure 18). The 11 of these on the Canadian side were occupied, from April to December, by internally-recording meteorological buoys, and by varying numbers of subsurface current-measuring buoys. At four of the stations, automatic temperature-profiling buoys were also installed. All of these Canadian buoys recorded their data internally, and these records were picked up regularly when the buoys were serviced by one of the major ships. The systems were ones with which their operators had had previous experience on the Great Lakes; overall, they proved quite reliable and a good data record was obtained.

Data from these buoys were complemented by those collected from the six shoreline meteorological stations situated along the Canadian shore, and from the three "Bedford Tower" platforms (Figure 18). The shoreline stations sampled atmospheric pressure, air temperature, dew point, precipitation, and wind speed and direction every ten minutes, recording the data on punched paper tape. The Bedford Towers - really very large taut-moored spar buoys provided by the Atmospheric Environment Service - sampled air temperature, dew point, and wind speed and direction at three levels above the lake surface; and precipitation and surface water temperature at a single level. Data from the towers were telemetered to associated shore stations, where they, too, were recorded on punched paper tape.

The U.S. network of buoys, towers, and land meteorological stations (the Physical Data Collection System - PDCS) was designed expressly to U.S. IFYGL specifications as an integrated, fully-automated data collection system. It included 10 research buoys (combination meteorological and limnological), four bottom-mounted offshore instrument towers, one island station (on Galloo Island at the Lake's eastern end), and five land meteorological and data relay stations.

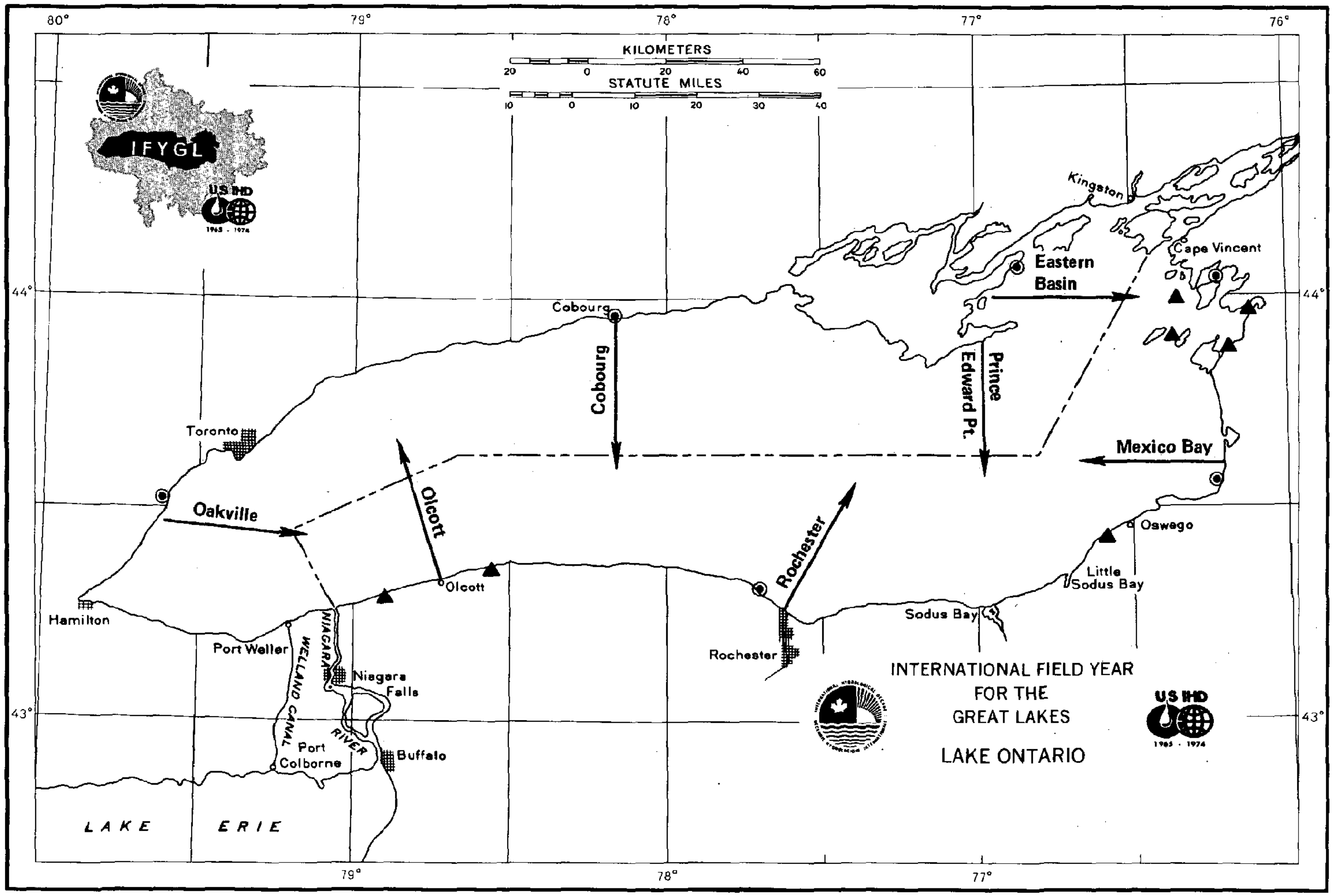

Figure 17. The approximate locations of the seven synoptic fishing areas. Where possible, samples were collected at depths of 9, 18, 27, 37, 55, 97, and 146 meters (plus additional stations in the deeper waters). (◎ primary shore stations; ▲ secondary shore stations)

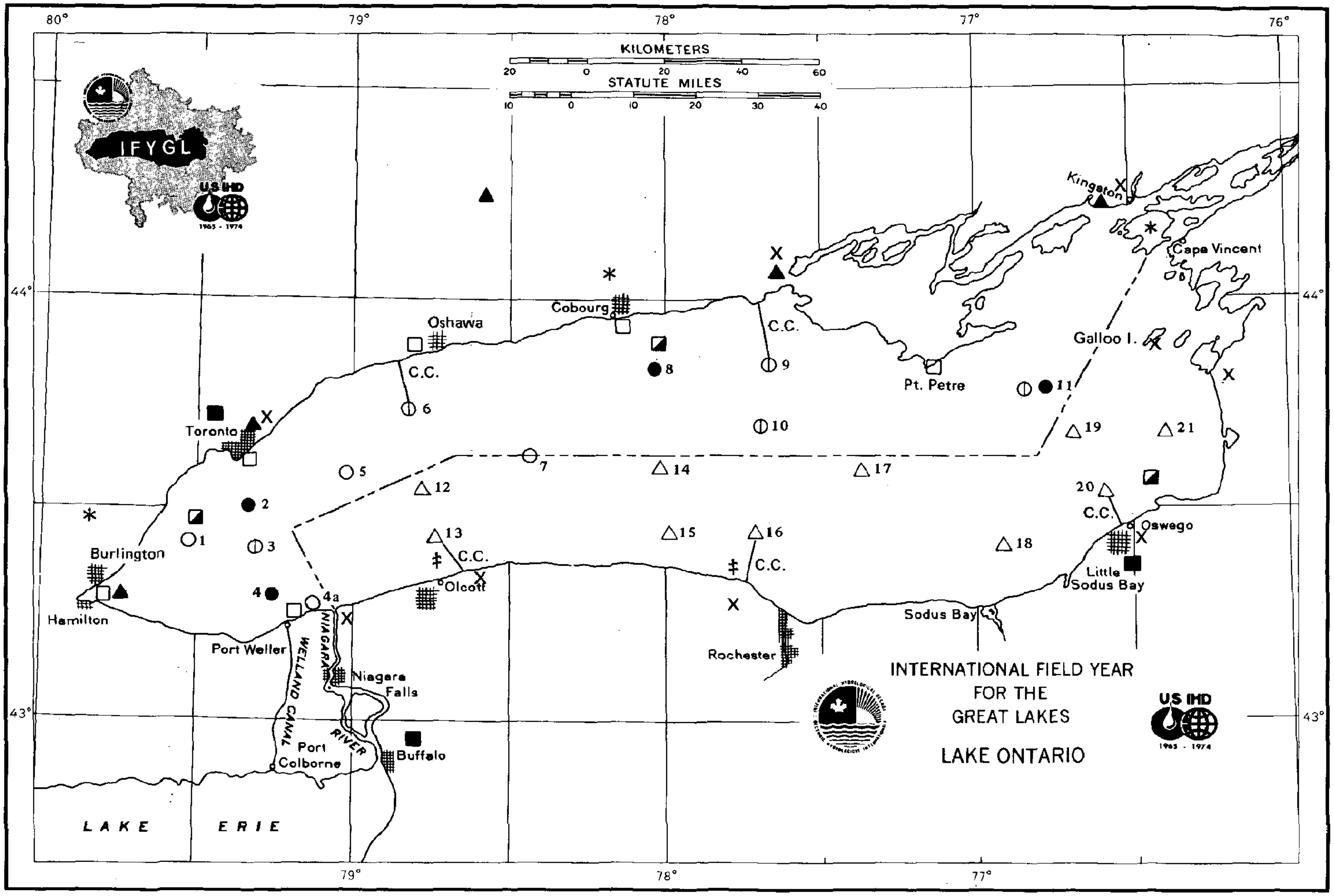

Figure 18. IFYGL fixed data collection sites. (○ Canadian, △ U.S. research buoy moorings; ⦶ thermistor chain; C.C.- coastal chain; ● wave mooring; □ shoreline station; ■ meteorological radar; X - meteorological land or island station; ▲ global solar and downward total radiation; ◪ Bedford buoy; ‡ U.S. tower; ✱ Decca navigation transmitter.)

Each of these sensing sites was interrogated automatically every six minutes by a control center located west of Rochester at one of the land meteorological stations. The resulting telemetered (by radio and wire) data was immediately transmitted on by land lines to Detroit, where it was recorded by the Lake Survey Center and initially processed. The Rochester PDCS Control Center also kept a backup tape of everything received from the field sites. Perhaps one of the greatest advantages of this system was the possibility of immediately examining the incoming data ("quick-look" analyses were also prepared weekly) to detect breakdowns in the system.

Because they were not designed to withstand the heavy icing conditions that exist on the Great Lakes in winter (Figure 19), both Canadian and U.S. buoys and towers were removed from the lake in early winter, 1972. However, one Canadian meteorological buoy was left out in mid-lake (at station 2), and functioned well, despite occasional heavy coating with ice. In order to collect as much data as possible over the winter (Lake Ontario rarely freezes over - most ice is usually located only at the eastern end), a lakewide network of nine Canadian current and temperature-measuring buoys, which have most of their components submerged, were set out in late November. These were retrieved in late March, 1973 after a successful winter (Figure 20).

Three meteorological radars were used in the Field Year (Figure 21), in the first comprehensive attempt to collect meaningful precipitation data over the lake on a continuous basis (a nearly impossible task by any other means). However, while the radars gave good descriptions of the location and areal extent of precipitation, they were not, in themselves, able to consistently measure the amount of rain- or snowfall. Consequently, networks of standard precipitation gauges were established at Bowmanville, Ontario, and outside Rochester, New York, to collect data for calibrating the radar outputs. A third network was set up near Oswego to calibrate the output of that radar during the winter. Extra care was exerted in selecting the sites for the precipitation gauges used in this "snow network" in order to reduce the "undercatch" of the gauges due to wind, and students from high schools in the area were enlisted to measure snow depths and identify crystal types. Unfortunately, relatively little snow fell in the area of the network during the 1972-73 winter.

Data from the Woodbridge radar was collected by photographing the scope at three-minute intervals, then digitizing and integrating the photographic images using a photoscanning device linked to a computer. The Oswego and Buffalo radars were equipped with an automatic, real-time digitizing system, backed up by scope photography. (The scope photographs proved invaluable later in providing data for periods when the automatic system was inoperative.)

Aircraft-collected data (Figure 22) includes standard meteorological measurements, high-altitude photography and multi-spectral scanning data, weekly airborne radiation thermometer (ART) surveys of lake surface temperature, and several periods of intensive, near-surface micro-meteorological measurements. These last-mentioned intensive studies were designed to complement similar but single-point measurements made by a group of instruments mounted on towers just off the mouth of the Niagara River for the Atmospheric Boundary

Figure 19. Winter operations aboard the Lac Erie, a small tugboat based at the Canada Centre for Inland Waters. (photo from CCIW)

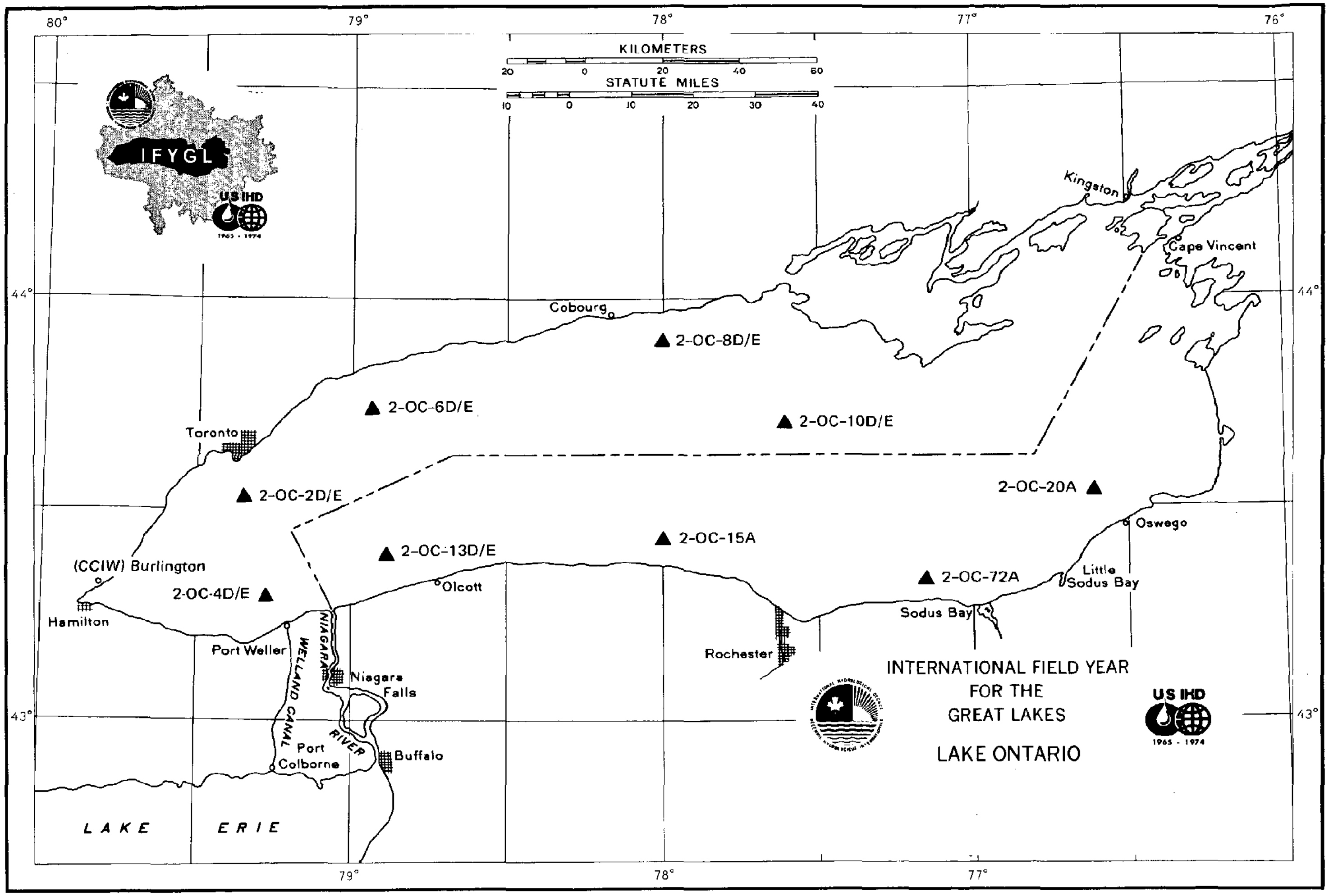

Figure 20. **Location of winter moorings, with CCIW identification numbers.** In addition, a surface meteorological buoy was set out in mid-lake off Toronto, where it functioned well, despite a heavy ice coating.

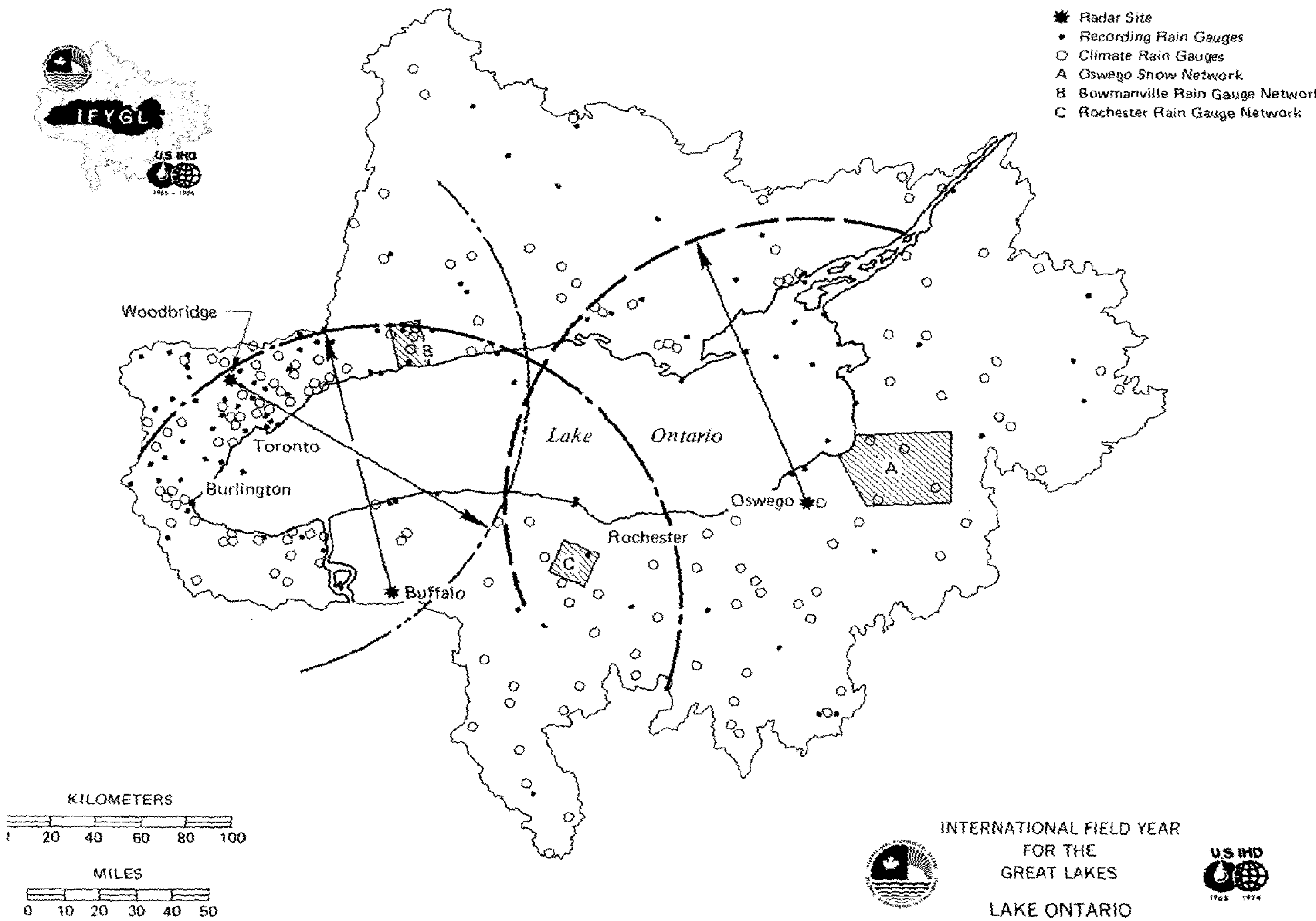

Figure 21. Sites of the meteorological radars, and rain and snow gauges and networks in the Lake Ontario basin.

Layer Program. Extremely high-altitude flights (with a U-2 and an RB-57 aircraft) also collected photographs in an effort to simulate satellite data, and these were to be compared with actual space imagery collected by the ERTS-1 satellite.

The rawinsonde system (Figure 22) operated only during the period from September 21 to December 11, 1972. During that period, four intensive periods were scheduled, in which the normal release schedule of two balloons per day was accelerated to eight releases per day at each of the six stations. The sondes used employed a relatively untried system that combined sonde location information with the usual telemetered metorological data. This was accomplished by having each sonde receive Loran-C navigational signals (regularly broadcast in the area as an aid to navigation) and re-transmit these to the ground stations. Surprisingly, in view of the essentially experimental nature of the system, the data collection results were better than those expected of standard rawinsonde systems used in weather forecasting. The sondes sent back data on temperature, humidity, and pressure every 0.8 seconds, both while rising and descending (on parachutes), giving a very fine picture of atmospheric structure over the lake.

Finally, one of the most important aspects of field operations was the regular and thorough intercomparison of the instruments employed, as well as their careful calibration before emplacement, during field operations, and after recovery from the various mounting platforms. For example, at several points during the Field Year, all the ships were brought together at one or more of the research buoys to simultaneously collect data sets to be compared with those from the buoy's instruments and those from the instruments on the other ships. Water samples were collected by two or more ships, steaming side-by-side, then divided, with part going to the other ship(s) for analysis, part being analyzed aboard the collecting ship, and part going ashore for analysis.

These intercomparisons and instrument calibrations completed the operational picture, making possible the fulfillment of the three objectives set out by the Steering Committee early in the scientific planning (see Chapter II): (a) improve the time-density and space-density of standard observations; (b) replicate the measurement of each parameter by as many methods as feasible; and (c) develop and/or utilize new methods and test these against an exceptionally good background of standard observations and data.

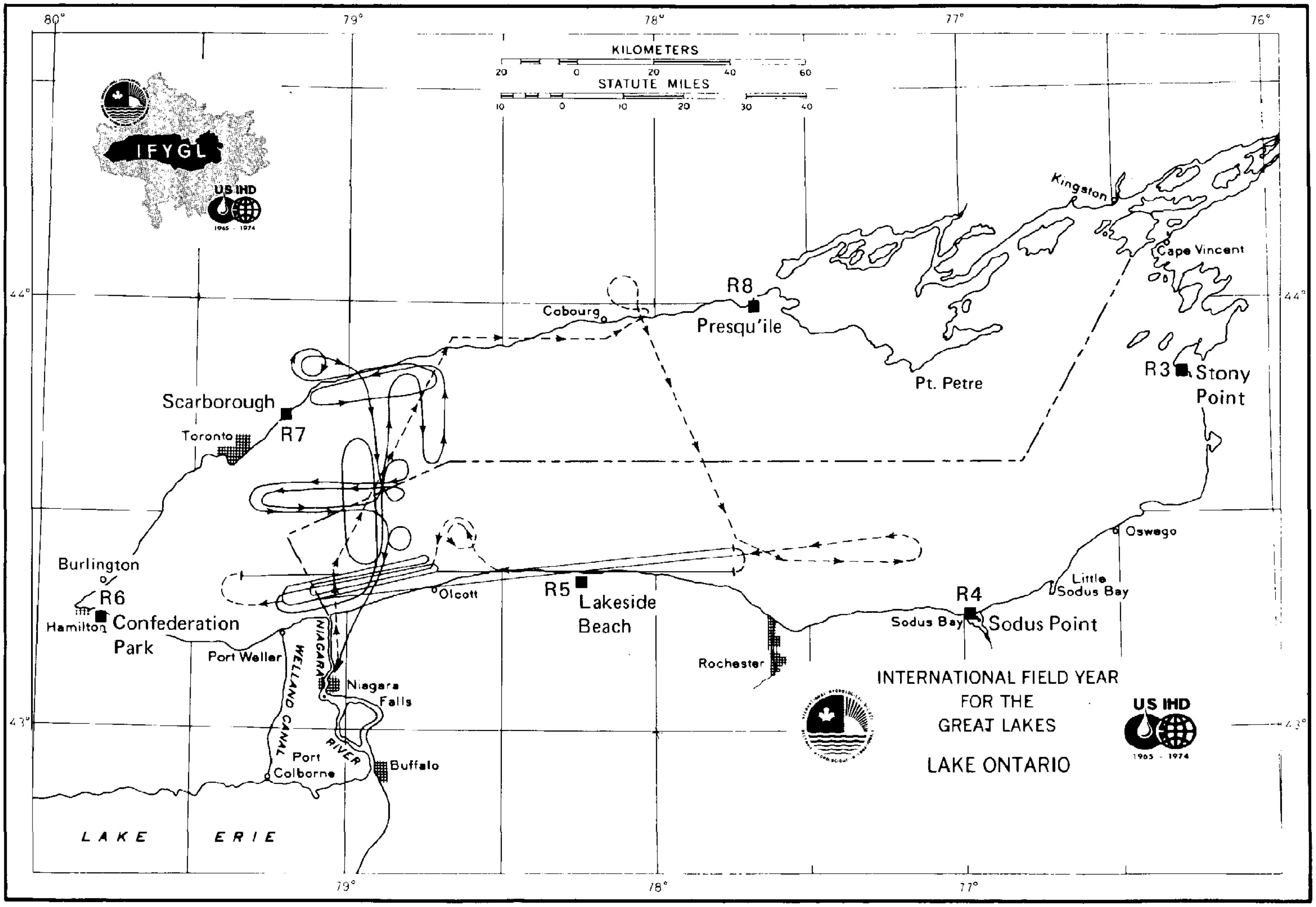

Figure 22. A sample research aircraft track (for the NOAA/RFF DC-6, 39C) and the rawinsonde sites (black squares). The multiple tracks off the mouth of the Niagara River are due to the presence there of the instrument towers for the Niagara Bar boundary layer study; each track is at a different altitude.

Chapter V

OUTPUT - THE DATA MANAGEMENT SYSTEM

PHILOSOPHY AND ORGANIZATION

It is in the data management system for the Field Year that the essential synergism of the program becomes most visible. The data system is the means by which the output of the great variety of IFYGL data sources is assembled, sorted, and packaged to fit the needs of those responsible for achieving the objectives of the nearly 150 scientific tasks. It is also the means of ensuring that all of the resulting data, analyses, and publications are properly stored and disseminated so as to be of maximum value to other present and future users.

Two basic policies concerning data generated in the Field Year were established early in the planning process. First, it has been a condition of participation that each of the investigators - whether an individual or an organization - agree to share all of the usable data collected (as soon as possible after their collection), as well as the results of subsequent analyses, with other investigators who need them. Second, the Steering Committee decided that "All data submitted to the (IFYGL) Archives is public property and will be released to any interested party(ies) subject only to the certification of the data validity by the party responsible for its collection, and (to) duplication costs."

While in theory the data management system works as a whole to bring together the collected data - from all sources - and re-distribute them as needed, in practice it is extremely diverse. Basically, data management is the responsibility of all participants. The system begins at the point of collection of the data from a sensor or from a non-IFYGL source, and extends to the IFYGL Archives that have been established in Canada and the United States.

The details of operation of the data management system are best understood through consideration of the roles played by the U.S. and Canadian Data Managers. While their specific functions differ appreciably, the two data managers are, in the end, the persons responsible for bringing together all that has been learned in the Field Year and for making it available through the official IFYGL Data Archives. They, plus those associates interested in any specific matter under discussion, also constitute the IFYGL Data Management Support Group. Like other support groups, this is a loose arrangement dedicated to coordination of operations and to quickly solving any problems that may arise.

In Canada, the IFYGL program is carried out through a "partnership" of provincial and federal government agencies, each of which is regularly involved in Great Lakes research as part of its basic mission. These agencies assumed the responsibilities for data collection, and subsequent analyses, as appropriate to their on-going interests and capabilities. However, those agencies, or groups within the agencies, that collected the data are not necessarily the ones responsible for their analysis. On the other hand, the data collecting agencies are responsible for the initial processing and verification of their data before turning them over to the Canadian Data Manager for re-distribution and entry into the IFYGL Data Archive.

The Canadian Data Manager is responsible for: (1) filing in a readily-accessible form the verified data presented to the archive by IFYGL investigators; (2) collecting and editing some of the data from the Canadian ships; (3) acquiring Canadian non-IFYGL data; (4) acquiring a complete set of the data collected by U.S. participants; (5) packaging and disseminating all of this data as required by the various Canadian principal investigators; (6) sending a complete set of Canadian data to the U.S. Data Manager; (7) maintaining a complete catalog of all the data collected in the Field Year and the resulting reports; (8) preparing a set of overall IFYGL data summaries to be filed in both archives as a rapid guide to the availability of verified data; and (9) coordinating and facilitating the flow of data within Canada, and between Canada and the U.S.A.

In Canada, the data will be physically stored at three locations. By far the largest of these is the IFYGL Data Archive at the Canada Centre for Inland Waters (CCIW). A second sizable store of data related to the meteorological aspects of the program and including non-IFYGL data, will be held at the Atmospheric Environment Service headquarters near Toronto, although some of this will be duplicated and stored at CCIW for the convenience of users. Remote sensing data, particularly imagery, will probably be kept at the Canada Centre for Remote Sensing in Ottawa because of the immense cost of duplicating it. Requests for all data are channeled through the Data Manager, however, and all the data collected in the Field Year will be available through him.

As in the case of data collection and analysis efforts, the Canadian data management functions are handled as part of on-going agency operations. The Canadian Data Manager is Head of the Data Management Section of CCIW's Scientific Operations Division. The section regularly handles the data management functions for all the programs at the Centre, of which IFYGL has been the largest. Eventually, the IFYGL data base will become part of the overall CCIW data bank, although it will be possible to access it separately.

In the United States, the Data Manager was directly involved in guiding the collection of data from the major IFYGL systems (PDCS and ships) in order to ensure that all necessary documentation was identified and preserved, and that the systems were appropriately checked, calibrated, and intercompared. ("Quick-look" analyses of the incoming data were made as a means of checking on system performance.) In addition, data from these systems directly entered the U.S. IFYGL data mangement system for initial processing, archiving, and some analysis. U.S. investigators collecting their own data with their own instruments, however, are considered to be responsible for those data until they are ready to turn them over to the U.S. Data Manager for archiving or wider dissemination. In general, the U.S. data management system is considerably more centralized than that in Canada, due largely to the Congressional designation of the National Oceanic and Atmospheric Administration (NOAA) as a "lead agency" for funding and managing the U.S. IFYGL program.

The U.S. Data Manager's respnsibilities include: (1) identifying non-IFYGL sources of information necessary to the IFYGL program and its investigators, and making that information available to them; (2) the direct collection of the data from the major U.S. systems (PDCS, ships, aircraft), their initial processing, and their dissemination to those who request them; (3) synthesis and analysis of

IFYGL data to serve both the immediate and long-term needs of Great Lakes resource managers; (4) preparation and maintenance of the overall IFYGL Data Catalog listing both the data acquired by the collection systems and that actually available in the two Archives; (5) coordination, liaison, and archiving functions similar to those described above for the Canadian Data Manager.

Since most of the biological and chemical data collected in the U.S. has been generated by the analysis of thousands of water and other samples in the Environmental Protection Agency (EPA) laboratories at Rochester and Grosse Ile, Michigan, those data have been entered directly in EPA's STORET environmental information system. The U.S. Data Manager is responsible for maintaining liaison with EPA, for assuring the availability of the biological and chemical data as part of the IFYGL Data Archive, and for providing background data to the STORET data bank to support biological and chemical analyses.

The U.S. Data Manager and his staff function as part of the NOAA IFYGL Project Office. However, both these personnel, and office and computer facilities, are provided and supported by another component of NOAA, the Center for Experiment Design and Data Analysis (CEDDA) of the Environmental Data Service (EDS). (Like the other parts of the project office, the Data Manager's section was specially-designated for the duration of the program)

DATA TYPES AND DATA FLOW

From the Data Managers' point of view, the entire IFYGL program can be seen in terms of the generation and flow of data. These data can be classified, according to their sources, in four areas: (1) internal data - i.e., data flowing directly from one or more sensing systems to the Data Managers; (2) principal investigators' data; (3) non-IFYGL data; and (4) other-country data. The amounts and kinds of data in each area, however, differ considerably between the Canadian and U.S. sides of the program, reflecting the differences between the multi-agency partnership in Canada and the lead agency approach in the United States. One of the strongest forces bringing these two approaches to the Field Year together is the IFYGL Data Management System.

Internal Data

This area is relatively more important in the United States, where all data from the basic data collection systems are handled directly or indirectly through the U.S. Data Manager in the IFYGL Project Office. These systems include the U.S. Physical Data Collection System (PDCS), the U.S. ships' data acquisition systems, the two U.S. radars, the Rochester precipitation network, the Oswego snow network, and the basic meteorological data collected by the airplane (DC-6 39C) from the NOAA Research Flight Facility in Miami. Data from both the Canadian and U.S. rawinsonde sites were also handled directly through the U.S. Data Manager.

Most of this data came in on magnetic tapes (the ship tapes were first processed by the Canadian Data Manager's office to convert the signal from analog to digital), although some was on punched paper tape, strip charts, or handwritten logs. However, the data from the largest single source on the U.S. side, the PDCS, were transmitted directly by radio and land lines to the NOAA Lake

Survey Center in Detroit for initial processing and conversion. Once a week these data were sent on to the data management staff in Washington, D.C. where "quick-look" analyses (such as the example in Figure 23) were produced as a means of checking on the performance of the system and of guiding field maintenance personnel in correcting problems as they arose. The ability to generate these "quick-look" analyses was one of the principal benefits of the automated PDCS, and contributed considerably to its success.

Canadian internal data consisted principally of data collected by the ships from the Canada Centre for Inland Waters. This came directly to the Canadian Data Manager for initial processing, editing, and entry into the IFYGL Archive. An initial data publication, providing a listing of the provisional data, was then produced for use in further editing and as a direct data source for users.

Principal Investigators' Data

These are IFYGL data collected and initially processed by individuals or institutions external to the Data Managers' offices. They reach the respective Data Managers in verified form, ready to be filed and distributed to other investigators in support of their tasks.

In Canada, where responsibility for the basic data collection was divided among several major provincial and federal government agencies, nearly all of the data fall into this category. The principal investigators (or data collectors) were responsible for submitting their collected data to the Data Manager in edited form, with a description of how the data were acquired, processed and edited. This includes data from the meteorological buoys, limnological buoys, evaporation stations, Bedford towers, stream gauges, observation wells, and aircraft data (such as produced by the airborne radiation thermometer). Some of these data, however, such as airborne imagery, satellite images from the Canadian ERTS receiving station, and some meteorological measurements are physically stored by the originating agencies, although cataloged in the IFYGL Archive.

In the U.S., this area generally consists of such items as the hand-collected data from the coastal chains, fine-scale measurements of wind structure made aboard the airplanes, and all of the U.S.-collected biological and chemical data (which are physically stored in the Environmental Protection Agency's STORET system). Since, in most cases, these data are specific to the studies of the investigators who collected them, they remain in their hands until analysis has been completed and the investigators are ready to turn over verified data and analyses to the archives for filing (Figure 24).

Non-IFYGL Data

These are gathered by both Data Managers from "standard" and "miscellaneous" sources. Since Canadian investigators typically have already-established data banks and libraries of pertinent information in their own agencies, somewhat less emphasis is placed on gathering this kind of data by the Canadian Data Manager. However, where the requisite data are not immediately available to the investigators, they are supplied as part of the data packages prepared by the Data Manager.

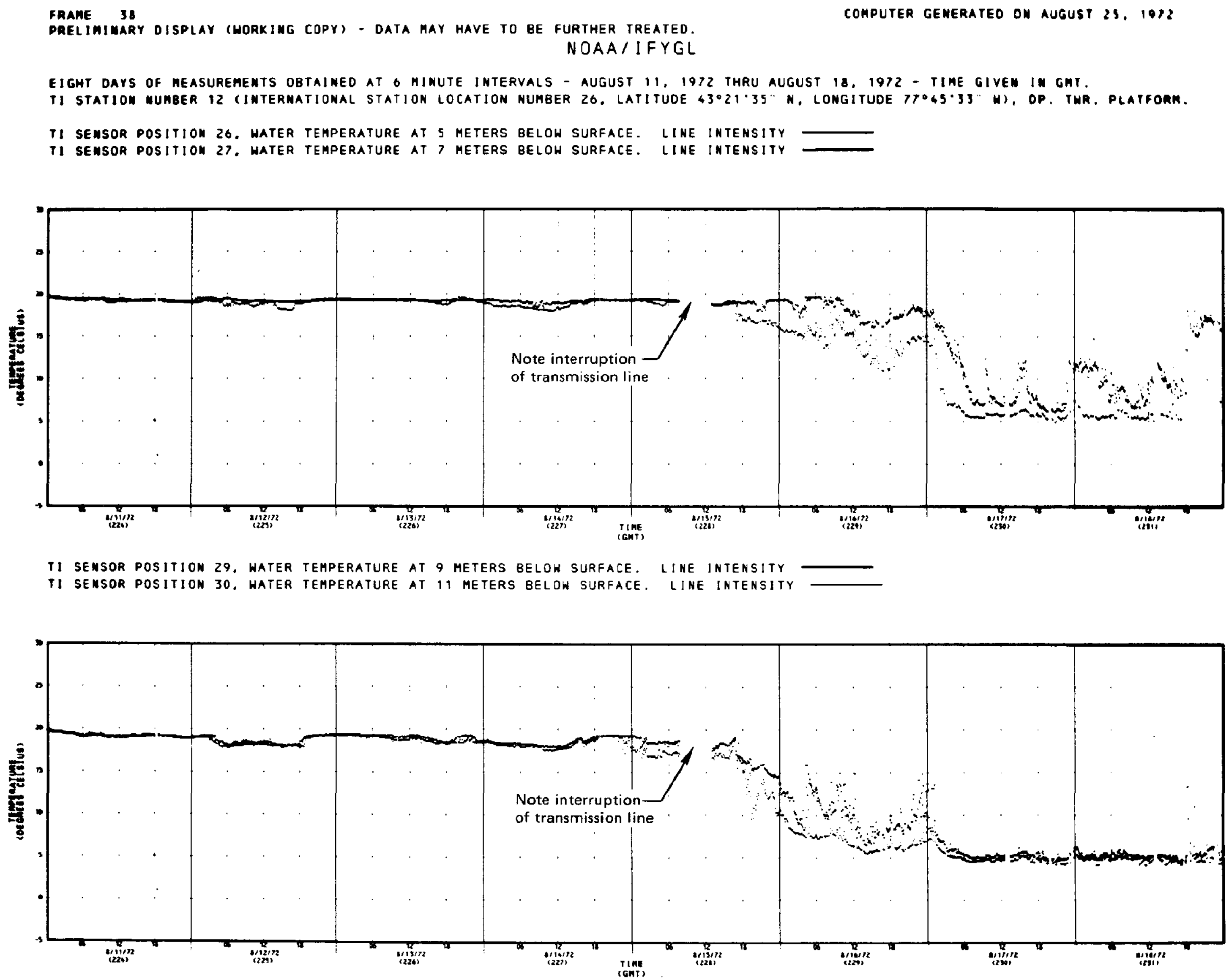

Figure 23. A sample graphical output of the "quick-look" analyses generated for the U.S. Physical Data Collection System. This shows the arrival of a mass of cold water at a buoy northeast of Oswego, New York. (prepared by NOAA IFYGL Project Office and NOAA Computer Division)

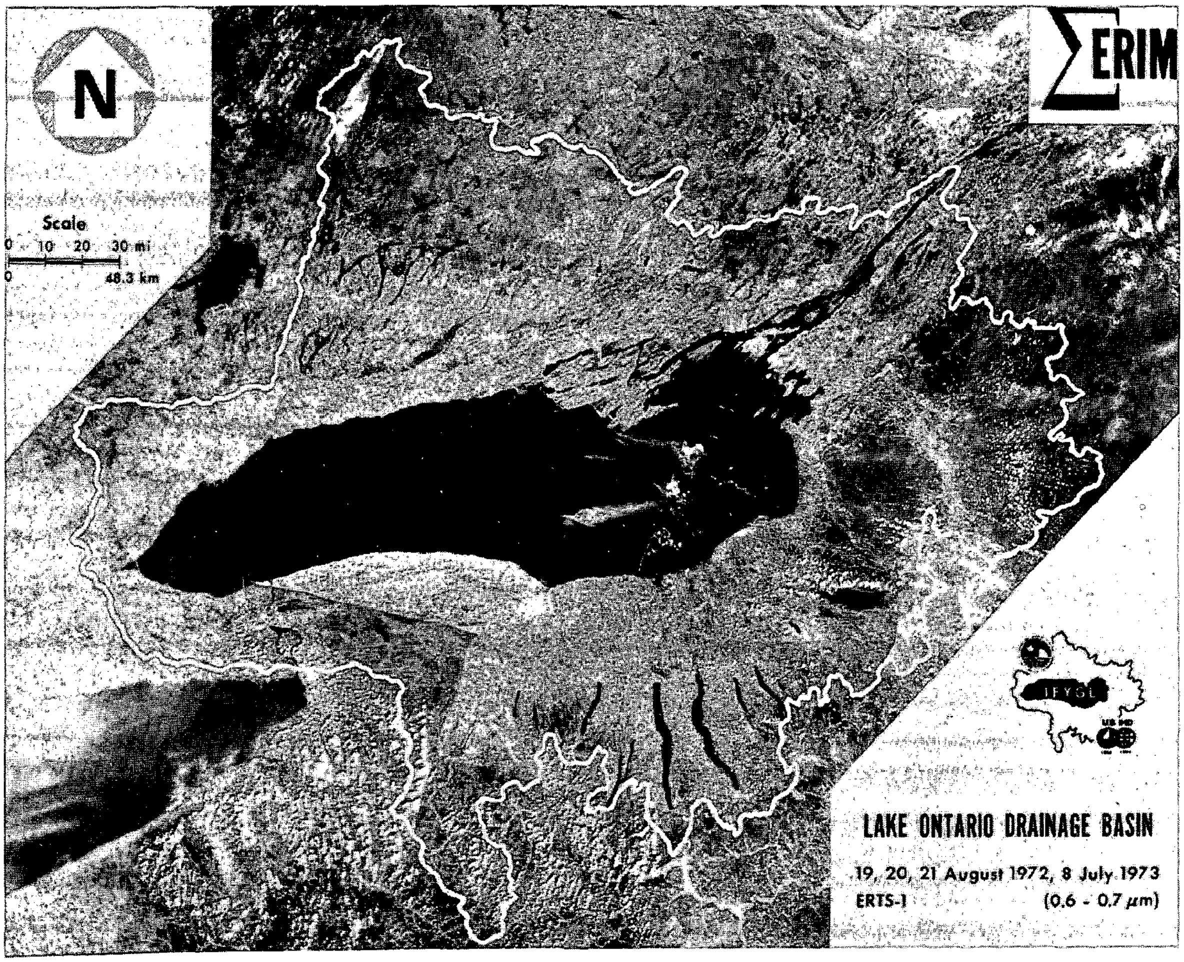

Figure 24. A mosaic of ERTS-1 satellite images of the Lake Ontario basin made by the Very High Resolution Radiometer in visible red light. This and other ERTS images are being used in an effort to map standing water and terrain features. (from: F. C. Polcyn, Environmental Research Institute of Michigan, Ann Arbor, Michigan)

Standard non-IFYGL data are those available through such agencies as the Canadian Atmospheric Environment Service or U.S. National Weather Service, where they are gathered and filed as part of day-to-day operations. This category includes such items as meteorological data collected for forecasting purposes, lake level data, and regular measurements of stream flow in the basin.

Sources of miscellaneous data are less easily identified, but may be invaluable to certain investigators. Meteorological investigations may be expanded considerably in areal coverage by the use of observations that may have been made by local high schools or individuals; commercial fishermen have long been an important source of information on the state of Great Lakes fisheries; individual scientists at area institutions may have records of natural phenomena collected for wholly unrelated purposes that can greatly improve IFYGL historical perspective, as well as contribute to the areal density, and therefore, accuracy, of present measurements. Finally, industries such as power plants often make their own chemical analyses of their effluents, as well as of the composition of the receiving waters, although this data is not usually routinely made public. Rather more of this kind of industry data is available in Canada for Lake Ontario because of the greater amount of industrial activity along the north shoreline.

Other-Country Data

This category consists of all the data collected, of whatever kind, in either the U.S. or Canada that may be of use to investigators on the other side of the border. It is listed as a separate area here because, from a Data Manager's point of view, these data can all be acquired from a single source: the other Data Manager. Eventually, of course, almost all of these data will be available in each of the Archives; those that are not can be easily obtained by direct contact with the storing agency, as well as through the respective Data Managers. Typically, requests to a Data Manager for data not present in his archive are passed on either through the other Data Manager or directly to the storing agency for direct delivery of the data to the requestor.

THE PRODUCTS

Processing and analysis of the mountains of data collected during the Field Year will continue for many years. However, it is possible now to assess the results in terms of both tangible products such as scientific papers and official reports, and intangible products such as the precedents that have been set, and friendships and the working relationships that have been established.

Many of the official reports of IFYGL activities are now in advanced stages of preparation, particularly those dealing with the various aspects of technical operations. Some other publications, such as the IFYGL Technical Plan, IFYGL Bulletin, and four Technical Manuals have already been published. A number of preliminary scientific reports have already been presented at major research meetings, and more are planned for the near future.

All this is in line with the official IFYGL publications policy which is "... to encourage prompt and widespread reporting of the results of individual Field Year projects, to ensure that adequate records are kept of project reports, to ensure that descriptions of the methods and techniques used in the program are disseminated widely, and to ensure the preparation of comprehensive, integrated reports."

A brief list of the tangible products that have resulted, or can be expected to result from Field Year efforts would include:

(1) Official Publications

  a. Technical Plan
  b. IFYGL Bulletin
  c. Technical Manuals
    i. summaries of available techniques
    ii. evaluation of IFYGL systems
  d. Scientific Reports
  e. Summary Reports of the Program

(2) Scientific papers in journals and at meetings

(3) Data Archives (including summaries, an inventory of collected data, a catalog of the Archive contents, and a description of the data collected)

(4) A program of synthesis and analysis conducted in the U.S. to meet the special needs of that country. (In Canada, these functions are handled by the existing responsible agencies on a somewhat more diverse basis.)

Intangible products are not so easy to define, but would include the experience gained by all participants - scientists, administrators, and support personnel - in planning, coordinating and carrying out a major international scientific program. Inasmuch as there has been some discussion of the possibility of fielding a similar program on at least one more of the Great Lakes, this experience may prove invaluable. Almost certainly, it will aid in carrying out the provisions of the recent bi-national Agreement on Great Lakes Water Quality that pledges both the U.S. and Canada to a vigorous program of improvement of the water quality in the Great Lakes.

The results of a number of tasks will be manifest in the development of improved mathematical models of the various natural processes in Lake Ontario and its basin. These models will be directly useful to Great Lakes planners and managers as stronger tools with which to understand present problems and predict the results of proposed actions affecting the Great Lakes. For example, a model of the lake energy balance will enable prediction of the effects, whether beneficial or deleterious, of additional thermal inputs from power plants, industry and municipalities; a model of lake-air interactions will enable better understanding of the unusual weather patterns in the region, and an improved assessment of the potential effects of weather modification proposals.

IFYGL Publications

The first of the official IFYGL publications to be prepared was the IFYGL Technical Plan. This four-volume compendium brought together a comprehensive description of the scientific objectives and plans, with a description of the facilities and operations intended to support their fulfillment. It provided an agreed-upon reference point and operational guidelines for all those participating in the Field Year to consult as work progressed. Thus, the Technical Plan has been one of the chief means of coordinating the activities of the scientists, administrators, technicians, ship crews, and others involved in the program.

The IFYGL Bulletin was actually the first IFYGL publication to be published; the first issue, based on material in the final draft of the Technical Plan, was issued in January, 1972. Since then, the Bulletin has been distributed to all IFYGL participants about four times a year, in volumes ranging in thickness from fewer than 40 to around 120 pages. The first two issues contain, respectively, summaries of the U.S. and Canadian plans for the Field Year. Subsequent issues have been divided into U.S. and Canadian sections, edited by the respective IFYGL Coordinators. These have reported on current IFYGL activities and, in later issues, preliminary results of the scientific tasks. The Bulletin has been particularly useful in keeping all IFYGL participants informed of the status of the overall program, as well as their own segment of it.

Four IFYGL Technical Manuals have been issued so far: Methods of Measuring Soil Moisture, Radiation Measurements, Measurement of Currents in the Great Lakes, and U.S. IFYGL Precipitation Data Acquisition System. The first three of these have not been detailed descriptions of the subject matter, but briefly survey the range and suitability of the various measurement techniques (and devices) available to the IFYGL Program. The last-mentioned, however, is a rather detailed report describing the system and its operation during the year of field data collection.

Additional manuals are planned, and these are also to be detailed reports on the actual operation of IFYGL Systems: the U.S. Physical Data Collection System, the U.S. ship data acquisition system, the IFYGL (joint) rawinsonde system, the Canadian shipboard data acquisition systems, and the Canadian current, and lake meteorological, measurement systems.

The scientific results of the Field Year Program will be summarized in a series of official Scientific Reports based on the results reported by the principal investigators of the 67 Canadian and 76 U.S. IFYGL tasks. There will be eight of these summary reports: seven describing results achieved in the six IFYGL Panel Program areas (a special report on Evaporation Synthesis has been split off from the overall Lake Meteorology and Evaporation report), and one entitled The IFYGL Program that is to serve as an overall scientific summary and evaluation. The first seven are being prepared by the panel co-chairmen; the last one is to be written by the co-chairmen of the Joint Management Team (who have also been appointed Scientific Editors for the entire series).

Scientific Papers

While the official IFYGL Scientific Report series will present summaries of the results of the IFYGL investigations, by far the bulk of the information resulting from the 143 tasks will be presented in scientific papers prepared by the investigators themselves and disseminated through standard scientific channels (e.g., journals, symposia, etc.). Each of these papers, however, is expected to be identified by its author(s) as stemming from the IFYGL Program, and copies when available are to be stored in the IFYGL Archives as part of the permanent, official collection of the results of the Field Year.

The flow of papers has already begun, notably through the medium of several symposia. The first of these was the 16th Conference of the International Association for Great Lakes Research (IAGLR), held in Huron, Ohio in April, 1973, which attracted 21 IFYGL scientific papers. Additional, less preliminary, papers will be presented at the 1974 IAGLR Conference. A series of papers, prepared largely by the panel and JMT co-chairmen, was presented in a half-day symposium devoted solely to IFYGL reports held as part of the 55th Annual Meeting of the American Geophysical Union on April 8, 1974.

IFYGL Data Archives

One of the important decisions made in setting up the IFYGL Program was that a central repository would be established for all the data collected, rather than leaving them in fragmentary form in the files of each participating agency or investigator. As noted before, it is through the mechanism of these archives, overseen by the data managers, that the synergistic strength of the IFYGL Program has been developed. Moreover, the archives are not only for the convenience of IFYGL investigators, but are to provide permanent, accessible storage of the data and information generated for the benefit of present and future managers and scientists considering lakes-related problems.

The exact form of the IFYGL Data Archives has not been entirely certain, but has come a step forward through publication of the IFYGL Archive Plan in early 1974. In Canada, the archive is located, as is the Data Manager's office, at CCIW, where both seem likely to remain. In the U.S., the bulk of the material will eventually be stored at the National Climatic Center in Asheville, North Carolina.

Only processed, verified data will be stored in the archives; raw data will generally be kept by the investigators or agencies that collected them. The storage system involves three levels: Level (1) comprises the data catalog, and data inventory, listing all the information available in and through each archive and delineating the success of the data collection operations; Level (2) will be a summarized data file, usable both as a convenient source of well-processed, selected data, and as a guide to access to Level (3); Level (3) is the main bank of all the processed observational data, as certified by the original investigators. Both countries are maintaining Level (3) files; Canada is preparing the Level (2) summaries, and the U.S. is responsible for Level (1).

During the operational Field Year, the Data Catalog served as a management tool, with monthly up-datings listing each task, its objectives (including a schedule for field measurement), and the progress made toward the data collection goals. Each month, every investigator received a questionnaire asking for a brief report on progress; the results of this continuing poll were entered in a computer at the National Oceanographic Data Center (NODC) and the catalog was printed out by the machine. Part of the catalog is a data inventory listing what was was actuallycollected by sensor and parameter. This is being published as a guide for investigators to use in planning their analyses to take advantage of periods for which full sets of data are available (not all kinds of data are available for the entire Field Year; occasional breakdowns of equipment account for gaps in the continuity of other items). A second catalog product is now in preparation, that will list everything actually stored in or available through the IFYGL Archives according to such descriptive terms as parameter observed, or relevant scientific problem area. This will serve as the means for future access to the archived data for both scientists and Great Lakes managers.

Application of the Results

A centralized program of synthesis and analysis of Field Year data has been undertaken by the U.S. Project Office in an effort to directly provide the means of improving the current level of management of the Great Lakes, especially on the U.S. side. The general approach to this effort was outlined in four steps:

1) Identify individuals and/or organizations that are responsible for management of water resources in the Great Lakes Basin, and determine their information requirements.

2) Analyze selected variables and derived parameters in order to increase understanding of the functional relations within the lake-atmosphere system. Special attention is paid to detailed analyses of the response of the system to well-defined natural phenomena such as storms and periods of upwelling.

3) Develop an information base containing the information needed in management decision processes, in a form that can be readily utilized by the managers.

4) Develop physical, biological, and chemical models of natural processes. These models are intended to provide the managers with the capability to predict the consequences of alternative courses of action in the Great Lakes.

Such a special effort was not needed in Canada, where information available from Field Year studies has already gone directly into the lake management decision-making process. Since the agencies conducting Field Year operations did so as part of their on-going responsibilities for Great Lakes research, the data and analyses have followed ready-made channels. A good example of these channels is the Environmental Quality Coordination Unit at the Canada Centre for Inland Waters. This group brings together research managers, administrators, and scientists with those who must make policy recommendations to Cabinet-level officials. For example, through the offices of the EQCU, IFYGL material is already incorporated in the International Joint Commission reports for 1972 on the state of the health of the Great Lakes.

The permanent addresses of the respective IFYGL Data Archives, through which the data and analyses generated in the Field Year can be obtained are:

(U.S.) Director
National Climatic Center
Federal Building
Asheville
North Carolina 28801

(Canada) IFYGL Data Archive
c/o Data Management Section
Canada Centre for Inland Waters
P.O. Box 5050
Burlington
Ontario L7R 4A6

Finally, in the U.S., as directed by the Steering Committee, arrangements have been made to have all official IFYGL publications, U.S. and Canadian, made available through the U.S. National Technical Information Service (NTIS). NTIS can provide either printed or microfiche copies; microfiche of any publication costs $1.45, postpaid. The price of hard copy depends on the length of the publication, but is usually moderate. The NTIS address is:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Appendix A

IFYGL SCIENTIFIC TASKS

INTRODUCTION

The following compilation of very brief summaries of the individual tasks in the IFYGL Program is organized under the six IFYGL panel program areas: Terrestrial Water Balance, Lake Meteorology and Evaporation, Energy Balance, Water Movements, Biology and Chemistry, and Atmospheric Boundary Layer. A seventh heading, "Other Tasks", includes such efforts as satellite remote sensing that are not strictly attributable to any one of the six panel areas, but that may apply to several of them in varying ways.

Each of the tasks listed in the following sections is numbered. These numbers were assigned in two entirely different ways in the United States and Canada; both systems are arbitrary and cannot be directly correlated. In Canada, they were assigned to tasks chronologically as they were added to the IFYGL Program, each number being followed by a two-letter descriptor indicating the panel program area to which it belonged. In the U.S., numbers were assigned on the basis of an alphabetical listing, in IFYGL Bulletin 3, of the U.S. tasks by the principal investigators' last names; later listings have been assigned numbers as they were approved. Each of the task numbers, however, is permanently assigned to a specific task; if the task is deleted, so is the number and it is not re-used. Thus, information on each task can be accessed through these numbers, although the IFYGL Data Archives are developing other means of access that should prove more useful.

The names and addresses listed are those available as of the fall of 1973. Changes in the list of tasks continue to occur; completely up-to-date listings are available through the Canadian IFYGL Coordinator, or the U.S. Project Office. A number of the tasks are specifically identified as joint tasks by having the names of principal investigators from both Canada and the United States listed with them. Many other tasks, however, are the beneficiaries of less formal, but effective cooperation among investigators working in the same, or closely allied, areas.

Of necessity, the outlines presented here barely begin to show the scope and depth of many of the tasks. Much more comprehensive, complete task descriptions are available in the IFYGL Technical Plan, Volume 1, Scientific Program; progress reports are published, as the information becomes available, in the IFYGL Bulletin; final reports will eventually be prepared as part of the series of scientific reports to be published by the IFYGL Steering Committee. All of these publications can be accessed through the IFYGL Data Archives, as noted in Chapter V.

TERRESTRIAL WATER BALANCE

United States Tasks

8 Runoff

Principal Investigator: L. T. Schutze, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231.

Objective: Determine the total monthly runoff from the Lake Ontario Basin into Lake Ontario from provisional streamflow data.

9 Evaporation

Principal Investigators: L. T. Schutze, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231; and D. F. Witherspoon, Great Lakes - St. Lawrence Study Office, Environment Canada, 318 Federal Building, Cornwall, Ontario K6J 5R8.

Objective: Compute the evaporation from the lake based on data gathered by other principal investigators in the Terrestrial Water Balance Program.

10 Simulation Studies and Analyses Associated with the Terrestrial Water Balance

Principal Investigators: B. G. DeCooke, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231; and D. F. Witherspoon, Great Lakes - St. Lawrence Study Office, Environment Canada, 318 Federal Building, Cornwall, Ontario K6J 5R8.

Objective: Analyze all data used in computing the evaporation values, and determine the statistical significance of each of the variables affecting the water balance relationship.

11 Land Precipitation Data Analysis

Principal Investigators: L. T. Schutze, and R. E. Wilshaw, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231.

Objective: Determine a land precipitation value for the U.S. side of the Lake Ontario Basin from selected index station data.

13 Soil Moisture and Snow Hydrology

Principal Investigator: W. N. Embree, U.S. Geological Survey, P.O. Box 948, Albany, New York 12201.

Objective: Obtain a best estimate of the changes in the quantity of water stored in the unsaturated zone, and collect data to better define the contribution of snow melt to soil moisture.

16 Lake Level Transfer Across a Large Lake

Principal Investigators: C. B. Feldscher, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226; and G. C. Dohler, Tides and Water Levels, Environment Canada, 615 Booth Street, Ottawa, Ontario K1A 0E4.

Objective: Evaluate the effects of wind, differentials in barometric pressure, tides, and water and air temperatures on the tilt or warp of the lake surface.

23 Inflow/Outflow Terms of Terrestrial Water Budget

Principal Investigator: I. M. Korkigian, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231.

Objective: Determine, by various measurement techniques, the inflow to Lake Ontario from the Niagara River and the Welland Canal, and the outflow from the lake through the St. Lawrence River (see Canadian task 46TW).

24 Use of an Unsteady-State Flow Model to Compute Continuous Flow

Principal Investigator: I. M. Korkigian, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231.

Objective: Develop a mathematical model of unsteady-state flow for the purpose of computing continuous flow.

30 Change in Lake Storage Term of Terrestrial Water Budget

Principal Investigator: R. E. Wilshaw, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231.

Objective: Determine the effect of gauge location on water level readings and storage determinations, and describe a gauge network that will best determine the change in storage.

31 Change in Land Storage

Principal Investigator: L. T. Schutze, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231.

Objective: Determine the change in the land storage term of the water budget for the U.S. side of the Lake Ontario Basin.

39 Airborne Snow Reconnaissance

Principal Investigator: E. L. Peck, Hydrologic Research and Development Laboratory, NOAA, Silver Spring, Maryland 20910.

Objective: Apply a combination of ground and airborne survey data of terrestrial gamma radiation levels to obtain the water equivalent profiles and mean water equivalents of snow along selected flight lines.

45 Mapping Standing Water and Terrain Conditions with Remote Sensor Data

Principal Investigator: F. C. Polcyn, Infrared and Optics Laboratory, University of Michigan, P.O. Box 618, Ann Arbor, Michigan 48107.

Objective: Obtain area and percentage of total area of standing water for representative watersheds, and measure areas and percentages of total area of various land uses to produce estimates useful in the computation of terrestrial storage and runoff.

48 Island - Land Precipitation Data Analysis

Principal Investigator: F. H. Quinn, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Install and operate precipitation gauges on and around Lake Ontario to provide data on the relationship of over-water to over-land precipitation. (see Canadian task 27ME)

52 Ground-Water Flux and Land Storage

Principal Investigator: E. C. Rhodehamel, U.S. Geological Survey, P.O. Box 948, Albany, New York 12201.

Objective: Determine the ground-water flux (volume per unit of time) flowing directly into Lake Ontario from stream interfluxes fronting on the lake, and the ground-water volume gained or lost from the overall land storage factor of the lake budget throughout the part of the Lake Ontario Basin lying in New York State.

58 Runoff Term of Terrestrial Water Budget

Principal Investigator: G. K. Schultz, U.S. Geological Survey, P.O. Box 948, Albany, New York 12201.

Objective: Compile streamflow data from areas with continuous recording gauges, and compute the weekly flow from about 3,000 mi^2, lying principally in the Lake Ontario Plain fronting Lake Ontario, that have none, or only a limited number, of gauges.

Canadian Tasks

11TW Monthly Water Balance of Basin

Principal Investigator: D. F. Witherspoon, Great Lakes - St. Lawrence Study Office, Cornwall, Ontario K6J 5R8.

Objective: Assemble monthly mean values of various parameters of the climate and hydrology of the land basin that are related to water balance, and compute evaporation, precipitation, run-off, moisture excess, and basin storage change in relation to other data.

13TW Groundwater Flow

Principal Investigator: D. H. Lennox, Hydrology Research Division, Environment Canada, Ottawa, Ontario K1A 0E7.

Objective: Determine groundwater flow into the lake from the Canadian side including assessment of the recharge, transmission, and discharge characteristics associated with the groundwater.

14TW Hydrology of Lake Ontario

Principal Investigator: E. A. MacDonald, Water Survey of Canada, Environment Canada, P.O. Box 335, Guelph, Ontario.

Objective: Collect and reduce stream flow data for Lake Ontario drainage in Canada.

38TW Groundwater Contribution to Lake Ontario

Principal Investigators: R. C. Ostry and S. N. Singer, Water Quantity Management Branch, Ontario Ministry of the Environment, Toronto, Ontario.

Objective: Determine the nature and quantity of groundwater flow into Lake Ontario during the Field Year, by the compilation of hydrogeological data in the form of bedrock and overburden well yields maps for the Lake Ontario drainage basin, and through detailed investigations into the groundwater regime of seven representative areas on the Canadian side of the basin, including an assessment of remote-sensed data as applied to hydrogeologic purposes.

46TW St. Lawrence - Niagara River Measurement Program

Principal Investigator: E. A. MacDonald, Water Survey of Canada, Environment Canada, P.O. Box 335, Guelph, Ontario.

Objective: Determine the outflow in the St. Lawrence River, and the inflow from the Niagara River and the Welland Canal. Inflow was to be measured by the Water Survey of Canada, and the outflow was to be measured by the Detroit District, U.S. Army Corps of Engineers (see U.S. TWB Task 23).

47TW Computer Modeling

Principal Investigator: L. E. Jones, University of Toronto, Toronto, Ontario.

Objective: Continue present research into the mathematical modeling of rainfall discharge data for the Rouge River basin, and into factors influencing water consumption in metropolitan Toronto.

49TW Snow Stratigraphy and Distribution in the Peterborough Area

Principal Investigator: W. P. Adams, Trent University, Peterborough, Ontario.

Objective: Study snow stratigraphy and distribution in a 500-acre property three miles north of Peterborough, and study the time profile at one site.

69TW Pleistocene Mapping

Principal Investigator: E. P. Henderson, Geological Survey of Canada, Ottawa, Ontario.

Objective: Prepare a Pleistocene map of the Lake Ontario Basin with inserts to show its glacial history.

74TW Water Level Network

Principal Investigators: G. C. Dohler, L. F. Ku, P. A. Bolduc, E. J. Minaker, Marine Sciences Directorate, Environment Canada, Ottawa and Burlington, Ontario.

Objective: (A) Evaluate the different components of water level fluctuations such as: (1) secular change; (2) seasonal change; (3) tides; (4) storm surges and wind set-up; and (5) natural oscillations. Any user will be able to obtain the direct information on water levels generated in this study by interrogating a computer. (B) Evaluate the computation of the mean water level of the lake for periods ranging from the short term (daily) to the long term (year).

78TW Basin Water Balance

Principal Investigator: M. Sanderson, University of Windsor, Windsor, Ontario.

Objective: Estimate by various methods the monthly terrestrial water balance for the Lake Ontario Basin during the Field Year.

108TW Lake Levels Transfer across Large Lakes

Principal Investigators: G. C. Dohler, Head, Tides and Water Levels; L. F. Ku, Officer-in-Charge, Applied Research; and P. A. Bolduc, Engineer, Marine Sciences Branch, Environment Canada, Ottawa and Burlington, Ontario.

Objectives: Evaluate quantitatively the effects of wind, differentials of barometric pressure, tides, and water and air temperature in terms of their variations as correlated with continuous water level recordings, simultaneously obtained at a series of stations covering the entire lake.

116TW Airborne Gamma Ray Snow Survey

Principal Investigator: H. S. Loijens, Glaciology Division, Inland Waters Directorate, Environment Canada, Ottawa, Ontario K1A 0E7.

Objectives: (1) Determine the accuracy of airborne gamma radiation measurements in measuring snow cover water equivalent. (2) Determine the feasibility of measuring the spatial variation of the snow cover over a large area.

LAKE METEOROLOGY AND EVAPORATION

United States Tasks

28 Cloud Climatology

Principal Investigator: W. A. Lyons, Department of Geography and Center for Great Lakes Studies, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201.

Objective: Develop a mesoscale climatology of insolation and clouds over Lake Ontario and surrounding areas.

36 Pan Evaporation Project (see Canada No. 65ME)

Principal Investigators: T. J. Nordenson, Acting Director, Hydrologic Research and Development Laboratory (W23), NOAA, Silver Spring, Maryland 20910; and J. A. W. McCulloch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Install and operate evaporation pan stations around Lake Ontario to provide data for computing daily "shallow" lake evaporation by four essentially independent techniques.

50 Atmospheric Water Balance (see Canada No. 66ME)

Principal Investigators: E. M. Rasmusson, Center for Experiment Design and Data Analysis, NOAA, 3300 Whitehaven St., Washington, D.C. 20235; and H. L. Ferguson, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Evaluate the heat and water balance of the lower and middle troposphere as a function of height and time; obtain estimates of the average evaporation from Lake Ontario for periods of approximately 1 week duration; investigate the character of synoptic-scale variations in evaporation and in the heat and water balance of the atmosphere; investigate the momentum and kinetic energy budgets of the lower troposphere.

51 Evaporation Synthesis (see Canada No. 62ME)

Principal Investigators: E. M. Rasmusson, Center for Experiment Design and Data Analysis, NOAA, 3300 Whitehaven St., Washington, D.C. 20235; and J. A. W. McCulloch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Review the evaporation estimates resulting from the evaluations of the lake energy balance, the terrestrial water budget, and the atmospheric water budget to derive best estimates of average evaporation for periods of from 1 to 2 weeks; based on these estimates, calibrate the estimates of lake evaporation derived from shoreline evaporation pan measurements.

69 Basin Precipitation - Land and Lake (see Canada No. 23ME)

Principal Investigators: J. W. Wilson, The Center for the Environment and Man, Inc., 275 Windsor Street, Hartford, Connecticut 06120; and D. M. Pollock, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Derive measurements of precipitation over Lake Ontario and its basin through the integration of data from the Canadian and U.S. weather radars and from all rain and snow gauges.

Canadian Tasks

16ME Airborne Radiation Thermometer (ART) Surveys

Principal Investigator: J. G. Irbe, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Make weekly airborne radiation thermometer surveys over the lake, and issue maps showing the isotherms of surface-water temperatures.

20ME Bedford Tower Program

Principal Investigator: J. A. W. McCulloch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Measure wind, temperature, and humidity at three levels, as well as precipitation and water temperature, and observe incoming radiation, using stable Bedford-type buoys at three locations.

21ME Canadian Shoreline Network

Principal Investigator: J. A. W. McCulloch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Install, operate, and maintain facilities for observing and recording air temperature, humidity, pressure, wind, and precipitation at six shoreline sites.

22ME Synoptic Studies

Principal Investigator: M. S. Webb, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Study in concert the various synoptic-scale meteorological events over and around Lake Ontario in order to learn about the weather systems generated by the lake, such as fog, and lake-effect snow.

23ME Radar Precipitation (see U.S. No. 69)

Principal Investigator: D. M. Pollock, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Determine the distribution of precipitation in time and space during the Field Year, using precipitation observations from all sources, including radar.

24ME Climatological Studies

Principal Investigator: D. W. Phillips, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Study the effects of Lake Ontario on the climate of its basin, using additional data from core networks.

25ME Evaporation by Mass Transfer

Principal Investigator: J. G. Irbe, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Estimate the evaporation for the whole lake, using the mass transfer technique.

26ME Wind and Humidity Ratios

Principal Investigator: M. S. Webb, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Re-examine, with the addition of Field Year data, previous work on ratios of over-lake to over-land wind, and of over-lake surface humidity to that found over-land.

27ME Island Precipitation Network

Principal Investigator: J. A. W. McCulloch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Deploy and operate an array of long-duration precipitation recorders established between Pt. Petre, and Main Duck Island, Ontario. (see U.S. task 48, TWB program)

62ME Evaporation Synthesis (see U.S. No. 51)

Principal Investigators: J. A. W. McCulloch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4; and E. M. Rasmusson, Center for Experiment Design and Data Analysis (D2), NOAA, 3300 Whitehaven St., Washington, D.C. 20235.

Objective: Estimate the evaporation from Lake Ontario, using data from other tasks: terrestrial water budget, energy balance, mass transfer, pan studies, atmospheric water budget, and micrometeorology. (This is a part of the joint Canadian/U.S. Synthesis Program.)

64ME Basin Evapotranspiration

Principal Investigator: H. L. Ferguson, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Determine, monthly, the potential and actual evapotranspiration from analysis of climatological data, complemented by that from the new networks, for the Canadian portion of the lake drainage basin.

65ME Special Shoreline Evaporation Pan Network (see U.S. No. 36)

Principal Investigator: J. A. W. McCulloch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Establish a network of evaporation pans (provided by the U.S.) around the lake shore, and, using the data from these and standard meteorological data, calculate evaporation and other factors in the energy balance.

66ME Atmospheric Water Balance (see U.S. No. 50)

Principal Investigator: H. L. Ferguson, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Conduct rawinsonde flights from six shoreline locations, three each on the Canadian and U.S. sides of Lake Ontario; estimate atmospheric moisture storage and moisture divergence, using rawinsonde, aircraft, and surface observations; and estimate the evaporation from the lake.

67ME Surface Water Temperature Distribution

Principal Investigator: M. S. Webb, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Abstract data for an array of grid points from maps containing monthly mean isotherms of the surface water temperatures of Lake Ontario based on airborne radiation thermometer (A.R.T.) surveys, and prepare from these data analyses of monthly spatial variations in the patterns of surface temperature, as well as areally-weighted means.

ENERGY BALANCE

United States Tasks

2 Net Radiation

Principal Investigator: M. A. Atwater, The Center for the Environment and Man, Inc., 275 Windsor Street, Hartford, Connecticut 06120.

Objective: Compute the net radiation flux (upward and downward) through the surface of Lake Ontario, using a numerical model to compute the flux at a number of points on a horizontal grid in order to obtain time sums of each of the radiative components.

17 Near-Shore Ice Formation, Growth, and Decay

Principal Investigator: A. Pavlak, General Electric Company, Valley Forge Space Center, P.O. Box 8555, Philadelphia, Pennsylvania 19101.

Objective: Design, fabricate, and deploy a system for gathering information on temperature fluxes at the land/air, air/water, and sediment/water interfaces on Lake Ontario; and develop a model for predicting ice formation, growth, and decay based on information on heat transfer at these interfaces.

18 Advection Term - Energy Balance

Principal Investigator: J. L. Grumblatt, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Develop the advection term in the general heat budget equation, using data from intensive measurement periods that coincide with those scheduled for the Terrestrial Water Balance program; compute an advection term bi-weekly.

40 Optical Properties of Lake Ontario

Principal Investigator: K. R. Piech, Cornell Aeronautical Laboratory, Inc., P.O. Box 235, Buffalo, New York 14221.

Objective: (1) Measure the optical properties of Lake Ontario, especially with reference to their spatial and temporal characteristics and photic zone definition; (2) Provide inputs to the lake heat budget and biological-chemical studies; and (3) Compare and evaluate three techniques for optical turbidity measurements (e.g., Secchi disk, irradiance meter/transmissometer, and aerial photographic photometry).

41 Storage Term - Energy Balance Program

Principal Investigator: A. P. Pinsak, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Test and correlate various methods used to measure and estimate lake heat storage, and apply these to the computation of the energy budget of Lake Ontario.

42 Sensible and Latent Heat Flux

Principal Investigator: A. P. Pinsak, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Based on detailed measured profiles of sensible heat flux or evaporation across the air-water interface, check the use of the Bowen Ratio in obtaining the sensible heat transfer and evaporative heat loss terms in the general energy budget equation; develop improved methods for parameterization of these terms.

54 Ice Studies for Storage Term - Energy Balance

Principal Investigator: F. H. Quinn, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Provide data for the lake heat storage term, as an aid both in achieving a better understanding of the role of ice and snow in this term, and in forecasting ice formation.

Canadian Tasks

8EB Shore Gauging Stations

Principal Investigator: D. G. Robertson, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Co-ordinate water temperature measurements with meteorological and water-level measurements from nearly the same locations on Lake Ontario.

32EB Thermal Bar Study

Principal Investigator: G. K. Rodgers, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Study the thermal bar and its development, and examine vertical circulation and temperature-depth profiles around the thermal bar.

36EB Electronic Bathythermograph

Principal Investigator: G. K. Rodgers, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Build and test an electronic bathythermograph for the measurement of a continuous temperature-depth profile, and for study of thermal fine structure in the Great Lakes.

42EB Heat Storage of Lake Ontario

Principal Investigator: F. M. Boyce, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Collect temperature profiles from the ship surveys, and compute the amount of heat stored in the lake in order to describe the energy fluxes.

63EB Airborne Ice Reconnaissance

Principal Investigator: T. B. Kilpatrick, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: To observe visually during airborne ice reconnaissance, and issue charts of the distribution of ice by type and percentage cover.

71EB Canadian Radiation Network

Principal Investigator: J. A. Davies, Department of Geography, McMaster University, Hamilton, Ontario.

Objective: Reduce and tabulate all Canadian IFYGL radiation data. The data was to be made available both as hard copy and on magnetic tape in the same format as the Radiation Summaries produced by AES.

72EB Floating Ice Research

Principal Investigator: R. O. Ramseier, Hydrologic Sciences, Environment Canada, Ottawa, Ontario.

Objective: Investigate the formation and growth of primary and secondary ice, ice thickness, and the mechanical properties of ice, by sampling in the Kingston-Oswego area.

73EB Terrestrial Heat Flow

Principal Investigator: A. Judge, Earth Physics, Department of Energy, Mines and Resources, Ottawa, Ontario.

Objective: Measure the rate at which heat flows between the lake and the sediments beneath, using oceanic heat flow techniques.

80EB Radiation Balance Program

Principal Investigator: J. A. Davies, Department of Geography, McMaster University, Hamilton, Ontario.

Objective: Study the radiation balance, including radiation flux, balance components, procedures for computing radiation, production of radiation climatology, and evaluation of radiation flux attenuation.

87EB Heat Flow to Lake Ontario

Principal Investigator: F. M. Boyce, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Determine the energy balance for Lake Ontario by estimating the heat advected to and from the lake through tributaries and outlets, using stream flow data and data on the quantities of heat entering the lake from the main thermal-electric power stations (Hearn, Lakeview, and Pickering).

88EB Temperature Measurements

Principal Investigator: F. M. Boyce, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Develop instrumentation and techniques for measuring the internal temperature of the lake as a function of time and location, and for processing and interpreting these measurements.

WATER MOVEMENTS

United States Tasks

27 Wave Studies (waverider buoys)

Principal Investigator: P. C. Liu, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Provide information with which to correlate the available theoretical models of wind-wave generation and assess their comparative applicability to Great Lakes waves.

34 Internal Waves - Transects Program - Interpretation of Whole-Basin Oscillations

Principal Investigator: C. H. Mortimer, Director, Center for Great Lakes Studies, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201.

Objective: Measure and analyze the variations in temperature distributions in two Lake Ontario cross sections to contribute to the understanding of the structure and mode of generation of upwelling and dominant internal wave patterns.

37 Simulation Studies and Other Analyses Associated With U.S. Water Movements Projects

Principal Investigators: J. P. Pandolfo and C. A. Jacobs, The Center for the Environment and Man, 275 Windsor Street, Hartford, Connecticut 06120.

Objectives: Modify an existing three-dimensional air-sea interaction model to simulate the three-dimensional circulation in an enclosed body of water of variable depth; simulate some typical dynamic conditions for Lake Ontario; and validate the model.

43 Thermal Characteristics of Lake Ontario and Advection Within the Lake

Principal Investigator: A. P. Pinsak, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Analyze the time-spatial variations in thermal structure within Lake Ontario, and correlate these with the forces acting on and within the lake, leading to a definition of the natural distribution and variability of heat within the lake.

47 Remote Sensing Study of Suspended Inputs Into Lake Ontario

Principal Investigators: F. C. Polcyn and C. T. Wezernak, Infrared and Optics Laboratory, University of Michigan, P. O. Box 618, Ann Arbor, Michigan 48107.

Objective: Define the diffusion and dispersion patterns of suspended solids loads introduced into Lake Ontario by tributary rivers, and of major industrial and municipal discharges.

49 Lake Circulation, Including Internal Waves and Storm Surges

Principal Investigator: D. B. Rao, Center for Great Lakes Studies, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201.

Objective: Use the dynamic principles of wind action on water bodies to describe the factors that govern selected circulation characteristics of Lake Ontario.

55 Lagrangian Current Observations

Principal Investigator: J. H. Saylor, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Measure Lagrangian current trajectories in Lake Ontario.

56 Circulation of Lake Ontario

Principal Investigator: J. H. Saylor, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Analyze current-meter measurements from the U.S. deep water buoy network for use in determining mean lake circulation.

59 Coastal Chain Program

Principal Investigator: J. T. Scott, Department of Atmospheric Sciences, State University of New York at Albany, Albany, New York 12203.

Objective: Provide near-shore lake water movement, and temperature data analyses to a variety of users.

72 Coastal Circulation in the Great Lakes

Principal Investigator: G. T. Csanady, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Objectives: Analyze and evaluate the north-shore Lake Ontario IFYGL coastal chain data, and compare them with south-shore data; Construct a theoretical model of the coastal boundary layer, taking into account nonlinear and frictional influences; Analyze data on coastal mass exchange episodes associated with current reversals; Construct a theoretical model of the mass-exchange process; and, Conduct a theoretical study of secondary circulations in the vicinity of upwellings.

75 Lake Circulation Model

Principal Investigator: J. R. Bennett, IFYGL Project Office/NOAA, 6010 Executive Blvd., EM-7 NBOC-1, Room 100, Rockville, Maryland 20852.

Objective: Develop a numerical model for prediction of lake currents and temperatures on time scales ranging from one day to a year. The model will be used to simulate the effect of wind and heat flux on the circulation of the lake and on the diffusion of dynamically passive substances. It will also be used to test the consistency of the lake measurements with the estimated surface fluxes of heat and momentum.

Canadian Tasks

3WM Statistical Prediction of Lake Currents

Principal Investigator: H. S. Weiler, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Design and test stochastic prediction models of the following types: (1) time autocorrelation, (2) exponential and non-linear smoothing, (3) adaptive smoothing, (4) regression methods (using overlake meteorological data), (5) "long-term" prediction and its stability in time, and (6) comparison of such schemes over space. Other models may be tried as necessary to improve prediction. (Data from task 45WM will be used.)

34WM Circulation Near Toronto

Principal Investigator: G. K. Rodgers, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Obtain a five-month continuous set of current data from a site near the Toronto shoreline for comparison with other current measurements in the IFYGL program.

40WM Coastal Chain Study

Principal Investigator: G. T. Csanady, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Objective: Describe coastal currents in Lake Ontario by measuring the currents and temperatures using the flag-chain technique, in two nine-mile sections at Oshawa and Pt. Petre.

43WM Internal Wave Measurements (transects)

Principal Investigator: F. M. Boyce, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Collect temperature profile information in order to study long and short internal wave activity.

45WM Lake Current Measurements

Principal Investigator: E. B. Bennett, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Establish the climatological and statistical characteristics of currents using data from self-recording current meters, monitoring water currents and temperature simultaneously at four depths at locations throughout Lake Ontario in conjunction with similar measurements by the U.S.

70WM Ground Truth for Remote Sensing

Principal Investigator: T. A. Falconer, Department of Geography, University of Guelph, Guelph, Ontario.

Objective: Obtain surface ground truth observations of a variety of parameters from the western end of the lake and the land part of the basin and relate these to remote-sensed data.

76WM Surface Wave Studies

Principal Investigator: G. L. Holland, Marine Sciences Branch, Environment Canada, 615 Booth Street, Ottawa, Ontario K1A 0E6.

Objective: Obtain data on the climatological aspects of wave motion, through the emplacement of three recording stations in the lake.

89WM Turbulent Diffusion Studies (joint with 114WM)

Principal Investigators: C. R. Murthy and K. C. Miners, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objectives: Determine the parameters of large-scale diffusion and evolve a generalized diffusion law, using fluorescent dye patches followed by aerial photography and fluorometric sampling. Establish a climatology of the coastal currents of the Great Lakes by measuring the vertical temperature profile, and meteorological data.

114WM Large Scale Diffusion Processes (this was merged with 89WM)

Principal Investigators: G. Kullenberg, Institute of Physical Oceanography, University of Copenhagen, Copenhagen, Denmark; H. Westerberg, University of Gothenberg, Gothenberg, Sweden; and K. C. Miners, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Determine the vertical and horizontal turbulent diffusion parameters, and study the dependency of the diffusion on simultaneously observed environmental factors, such as wind conditions, and vertical and horizontal content- and density-structures. Of special interest is the relationship between the thermal structure and the vertical diffusion. A technique for making the observations by means of dye tracing has been developed and used in coastal and offshore waters (the Kattegatt, the Skagerrak, the Baltic).

95WM Hydrodynamic Modeling

Principal Investigator: J. Simons, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Develop and test multi-level numerical models of Lake Ontario and Lake Huron in order to examine hydrodynamic and thermodynamic processes. (Models of this type are suitable for forecasting and hindcasting large-scale processes, and may be developed in a broader sense for similar examinations of biological/chemical/geological processes.)

109WM Upwelling Study

Principal Investigator: G. K. Rodgers, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Provide detailed information on the lake thermal structure during periods of upwelling along the northwest portion of Lake Ontario.

110WM Hydro Intake Study

Principal Investigator: A. Arajs, Ontario Hydro, Toronto, Ontario.

Objective: Determine the temperature and current climatology relevant to water intake pipe locations of proposed Ontario Hydro generating stations.

111WM Lakeview Dispersion Study

Principal Investigator: M. D. Palmer, Water Quality Branch, Ontario Ministry of the Environment, Toronto, Ontario.

Objective: Obtain continuous current and temperature records simultaneously from several current meters in the nearshore region off Lakeview, west of Toronto, in order to determine water movement characteristics for a proposed sewage outfall.

115WM Wave Climatology of Lake Ontario by Visual Wave Observation

Principal Investigator: H. K. Cho, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Make and record visual wave observations from the major IFYGL research vessels to establish the climatological characteristics of wind waves in Lake Ontario.

BIOLOGY AND CHEMISTRY

United States Tasks

1 Phosphorus Release and Uptake by Lake Ontario Sediments

Principal Investigators: D. E. Armstrong, and R. F. Harris, Water Chemistry Program, University of Wisconsin, Madison, Wisconsin 53706.

Objective: Determine the amounts and the forms of phosphate in the sediments of Lake Ontario, their relative mobility within different sediments and sedimentary environments, and the phosphorus balance between sediments and the lake waters at the sediment-water interface.

4 Nitrogen Fixation

Principal Investigator: R. Burris, Department of Biochemistry, University of Wisconsin, Madison, Wisconsin 53706.

Objective: Measure nitrogen fixation by blue-green algae in order to improve understanding of the relationship of nutrients and algae.

6 Status of Lake Ontario Fish Populations (cooperative fisheries study; see task 83BC)

Principal Investigator: J. F. Carr, Great Lakes Fishery Laboratory, Bureau of Sport Fisheries and Wildlife, Department of the Interior, 1451 Green Road, P. O. Box 640, Ann Arbor, Michigan 48107.

Objective: Describe the species composition of Lake Ontario fish stocks, their distribution, relative abundance, growth rates, and incidence of lamprey predation; determine the major food pathways (materials transfer) among the fish populations; and evaluate the influence of environmental factors on the distribution of fish stocks through correlation with other pertinent IFYGL data.

7 Materials Balance of Lake Ontario

Principal Investigator: D. J. Casey, Rochester Field Station, Environmental Protection Agency, University of Rochester, Rochester, New York 14612.

Objective: Determine the form and the amount of materials entering, leaving, and residing in Lake Ontario, with emphasis on basic plant nutrients and, to a lesser extent, on heavy metals.

12 Transport Processes Within the Rochester Embayment of Lake Ontario

Principal Investigators: W. H. Diment, G. F. Bonham-Carter, and J. H. Thomas, Department of Geological Sciences, University of Rochester, Rochester, New York 14627.

Objective: Develop a basis for predicting the quality of water within the embayment as a function of time and position from a knowledge of season and wind history; and study the impact of a large river and large metropolitan-industrial community on a near-shore zone of Lake Ontario.

19 Occurrence and Transport of Nutrients and Hazardous Polluting Substances in the Genesee River Basin

Principal Investigator: L. J. Hetling, Director, Environmental Quality Research, New York State Department of Environmental Conservation, 50 Wolf Road, Albany, New York 12201.

Objective: Investigate the sources and rates of discharge of various hazardous polluting substances and nutrients in the Genesee River Basin and determine the history of these pollutants in terms of the rate of transportation, storage, and decay within the streams.

21 Hazardous Materials Flow

Principal Investigators: T. T. Davies (Coordinator), Office of Research and Monitoring, Environmental Protection Agency, Grosse Ile Field Station, Grosse Ile, Michigan 48138; R. L. Booth (Organic Materials), Analytical Quality Control Laboratory, Office of Research and Monitoring, Environmental Protection Agency, Cincinnati, Ohio 45268; D. J. Casey (Routine Metals), Rochester Field Station, Environmental Protection Agency, Region II, University of Rochester, Rochester, New York 14612; W. T. Donaldson (Specific Metals), Southeast Water Laboratory, Office of Research and Monitoring, Environmental Protection Agency, Athens, Georgia 30601; R. B. Moore (Pesticides), Lake Ontario Environmental Laboratory, State University College, Oswego, New York 13126; and R. J. Velten (Radioactive Materials), Office of Operations, Environmental Protection Agency, 5555 Ridge Avenue, Cincinnati, Ohio 45268.

Objective: Determine the amounts of hazardous materials entering, leaving, and residing within Lake Ontario, and the distribution of hazardous materials in the various trophic levels and in the various media within the lake.

22 Remote Measurement of Chlorophyll with Lidar Fluorescent System

Principal Investigator: H. H. Kim, Applied Science Division, Wallops Island Station, National Aeronautics and Space Administration, Wallops Island, Virginia 23337.

Objective: Field test and evaluate a Lidar Fluorescent System (airborne laser fluorometer) for remote measurement of surface chlorophyll a distribution.

26 Algal Nutrient Availability and Limitation on Lake Ontario

Principal Investigators: G. F. Lee, N. Sridharan, and W. Cowen, Water Chemistry Program, University of Wisconsin, Madison, Wisconsin 53706.

Objective: Describe the sources and availability of nutrients, and determine which nutrient is rate limiting or can be made rate limiting.

29 Zooplankton Production in Lake Ontario as Influenced by Environmental Perturbations

Principal Investigator: D. C. McNaught, Department of Biological Science, State University of New York at Albany, Albany, New York 12203.

Objective: Describe the seasonal zooplankton production for all of Lake Ontario, including the taxonomy of the population and an assessment of the total biomass present. The ultimate goal of this program is to understand how increased pollution has altered the zooplankton populations of the lake, and to develop predictive capabilities to head off pollution problems as they develop.

33 Near-Shore Study of Eastern Lake Ontario

Principal Investigator: R. B. Moore, Lake Ontario Environmental Laboratory, State University of New York at Oswego, Oswego, New York 13126.

Objective: Gather basic information on the changes in chemistry, biology, and to some extent, the physical environment of eastern Lake Ontario through the Field Year.

35 Pontoporeia affinis and Other Benthos in Lake Ontario

Principal Investigator: S. C. Mosley, Great Lakes Research Division, University of Michigan, Ann Arbor, Michigan 48104.

Objective: Document seasonal and regional differences among populations of Pontoporeia affinis, an important fish forage organism, and relate these to environmental differences.

44 Oswego Harbor Studies

Principal Investigator: A. P. Pinsak, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Investigate the critical water quality parameters in Oswego Harbor and in the area of diffusion in the adjacent portion of Lake Ontario on a time-spatial basis.

46 Remote Sensing Program for the Determination of Cladophora Distribution

Principal Investigators: F. C. Polcyn and C. T. Wezernak, Infrared and Optics Laboratory, University of Michigan, P. O. Box 618, Ann Arbor, Michigan 48107.

Objective: Delineate the distribution and areal coverage of Cladophora along the entire shore of Lake Ontario and estimate its biomass by use of remote sensing techniques, including both aircraft and satellite (ERTS-1) data.

53 Spring Algal Blooms

Principal Investigator: A. Robertson, U.S. IFYGL Project Office/NOAA, EM-7 NBOC-1, Room 100, Rockville, Maryland 20852.

Objective: Determine in detail the changes in concentration of plant nutrients and certain related biological properties in Lake Ontario during the spring and early summer.

60 Analysis of Phytoplankton Composition and Abundance

Principal Investigator: E. F. Stoermer, Great Lakes Research Division, University of Michigan, North University Building, Ann Arbor, Michigan 48105.

Objectives: Determine the abundance and distribution of the phytoplankton populations of Lake Ontario and relate them to key environmental factors. A secondary, but very important, objective is to collect and preserve archival material to serve as a baseline with which to compare the results of future studies. Such information has been lacking for Lake Ontario.

62 Analysis and Model of the Impact of Discharges From the Niagara and Genesee Rivers on Near-Shore Biology and Chemistry

Principal Investigator: R. A. Sweeney, Great Lakes Laboratory, State University of New York at Buffalo, 5 Porter Avenue, Buffalo, New York 14201.

Objective: Study the basic trophic levels in cooperation with the main lake phytoplankton, zooplankton, and benthic organism studies programs, and model the near-shore processes.

64 Mathematical Modeling of Eutrophication of Large Lakes

Principal Investigator: R. V. Thomann, Civil Engineering Department, Manhattan College, Bronx, New York 10471.

Objective: Construct a mathematical modeling framework of the major features of eutrophication in large lakes.

66 Sediment Oxygen Demand

Principal Investigator: N. A. Thomas, Grosse Ile Field Station, Office of Research and Monitoring, Environmental Protection Agency, Grosse Ile, Michigan 48138.

Objective: Measure the oxygen demand of the sediments of Lake Ontario.

67 Main Lake Macrobenthos

Principal Investigator: N. A. Thomas, Grosse Ile Field Station, Office of Research and Monitoring, Environmental Protection Agency, Grosse Ile, Michigan 48138.

Objective: Determine the biological quality of Lake Ontario as reflected by the abundance, composition, and distribution of the benthic community, and relate the community structure to water chemistry measurements.

68 Exploration of Halogenated and Related Hazardous Chemicals in Lake Ontario

Principal Investigators: G. F. Lee and C. L. Haile, Water Chemistry Program, University of Wisconsin, Madison, Wisconsin 53706.

Objectives: Analyze fish, plankton, benthic fauna, sediments, and water collected from Lake Ontario for a wide range of toxic organic chemicals, and determine the base level concentration of these materials.

71 Distribution, Abundance, and Composition of Invertebrate Fish - Forage Organisms in Lake Ontario

Principal Investigator: J. F. Carr, Great Lakes Fisheries Laboratory (BSFW), Department of the Interior, Ann Arbor, Michigan 48107.

73 Lake Water Characteristics

Principal Investigator: A. P. Pinsak, NOAA Lake Survey Center, 630 Federal Building and U.S. Courthouse, Detroit, Michigan 48226.

Objective: Measure and analyze the vertical and lateral distribution, as well as variation with respect to time, of the chemical and physical properties of Lake Ontario and its immediate environment. The aim is to provide the basic information necessary to define time-spatial relationships of significant water characteristics in the lake.

76 Lake Ontario Invertebrate Fauna List

Principal Investigator: A. Robertson, U.S. IFYGL Project Office/NOAA, EM-7 NBOC-1, Room 100, Rockville, Maryland 20852.

Objective: Determine which invertebrate species have been reported from Lake Ontario, and which of these species are of sufficient importance to the lake ecosystem to be considered in modeling biological processes within the lake.

Canadian Tasks

54BC Groundwater Supply near Kingston

Principal Investigator: W. A. Gorman, Queen's University, Kingston, Ontario.

Objective: Sample the water of Deadman Bay, near Kingston, and of influent streams to determine the geochemistry of the bay, how it is affected by the inflow, and the nature of the seasonal variations that occur.

81BC Materials Balance - Lake Ontario

Principal Investigator: S. Salbach, Water Quality Branch, Ontario Ministry of the Environment, Toronto, Ontario.

Objective: Measure the quantities of nutrients that promote the growth of algae, and of toxic chemicals flowing into and out of the lake from Canadian rivers, sewage treatment plants, and industrial plants.

83BC Cooperative Studies of Fish Stocks (see U.S. BC task 6)

Principal Investigator: W. J. Christie, Glenora Fisheries Station, Ontario Ministry of Natural Resources, R. R. #4, Picton, Ontario K0K 2T0.

Objectives: Establish the growth rates, stocks, and distribution of various fish types, and study the food (and pollutant) pathways from one species to the other. Assess research vessel sampling as a means of monitoring the success of present and future management activities.

84BC Cladophora Growth

Principal Investigator: G. E. Owen, Water Quality Branch, Ontario Ministry of the Environment, Kingston, Ontario.

Objective: Investigate the distribution and abundance of Cladophora in Lake Ontario, and evaluate the application of remote sensing techniques to these investigations.

85BC Nutrient Cycles - Lake Ontario (Ontario Organic Particle Study)

Principal Investigator: P. Stadelmann, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Investigate nutrient chemical cycles at various sampling depths and stations in conjunction with eight Ontario Organic Particle Study (OOPS) cruises planned for the Field Year.

86BC Lake Ontario Surface Chlorophyll a Survey

Principal Investigator: H. F. Nicholson, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Study the temporal and horizontal distribution of chlorophyll a and particles along with selected physical and chemical parameters (particularly temperature).

Note: The following four tasks form a sub-project aimed at determining the load distribution and turnover time of plankton in the lake.

98BC Lake Ontario Cross-Section Study

Principal Investigators: G. Carpenter, M. Munawar, and I. F. Munawar, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Measure the patchiness, diurnal vertical migration, and horizontal transport of zooplankton.

101BC Lake Ontario Primary Production Study

Principal Investigators: P. Stadelmann, M. Munawar, and I. F. Munawar, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Measure primary biological production in the lake and compare the various methods of measurement used.

102BC Lake Ontario Diel Pigment Variation

Principal Investigators: W. Glooschenko, M. Munawar, and I. F. Munawar, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Measure short-term variations of phytoplankton pigments.

104BC Rain Quality Monitoring

Principal Investigator: P. Stadelmann, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Measure the atmospheric chemical input to the lake from rain, dust, and snowfall.

103BC Pesticide Concentration in Bird Eggs

Principal Investigator: M. Gilbertson, Toxic Chemicals Section, Canadian Wildlife Service, Ottawa, Ontario K1A 0W1.

Objectives: Document (1) the extent of the factors affecting the breeding success of aquatic fish-eating birds in the Great Lakes, (2) the extent of population changes from the past, (3) the present colony size and distribution (to enable assessment of future changes), (4) the distribution of toxic residues in the lakes, and (5) the effect of toxic residues on breeding success.

112BC Structure and Ecologic Relations in the Threespine Stickleback

Principal Investigator: E. T. Garside, Dalhousie University, Halifax, Nova Scotia.

Objective: Elucidate the ecologic role of the Threespine Stickleback in Lake Ontario.

ATMOSPHERIC BOUNDARY LAYER

United States Tasks

3 RFF/DC-6 Boundary Layer Fluxes

Principal Investigator: B. R. Bean, Wave Propagation Laboratory, NOAA, Boulder, Colorado 80302.

Objective: Determine the fluxes of water vapor, heat, and momentum over Lake Ontario using the instrumentation mounted on the DC-6 airplane of the NOAA Research Flight Facility (RFF).

5 Profile Mast and Tower Program

Principal Investigator: J. A. Businger, Department of Atmospheric Sciences, University of Washington, Seattle, Washington 98105.

Objective: Study air-mass modification and internal boundary layer formation as cold air from the land passes over the relatively warm lake.

14 Boundary Layer Structure and Mesoscale Circulation

Principal Investigator: M. A. Estoque, School of Marine and Atmospheric Sciences, University of Miami, P. O. Box 9115, Coral Gables, Florida 33124.

Objective: Determine the structure and behavior of mesoscale atmospheric disturbances produced by Lake Ontario.

15 Mesoscale Simulation Studies

Principal Investigator: M. A. Estoque, School of Marine and Atmospheric Sciences, University of Miami, P. O. Box 9115, Coral Gables, Florida 33124.

Objective: Construct theoretical models of two types of mesoscale phenomena produced by Lake Ontario.

20 Boundary Layer Flux Synthesis

Principal Investigator: J. A. Almazan, Center for Experiment Design and Data Analysis, NOAA, 3300 Whitehaven St., Washington, D.C. 20235.

Objective: Develop, from IFYGL tower, aircraft, buoy, captive balloon, indirect sensor, and surface data, best estimates of vertical eddy fluxes of sensible and latent heat, water vapor, and momentum in the atmospheric surface layer over Lake Ontario.

25 Radiant Power, Temperature, and Water Vapor Profiles Over Lake Ontario

Principal Investigator: P. M. Kuhn, Atmospheric Physics and Chemistry Laboratory, NOAA Environmental Research Laboratories, Boulder, Colorado 80302.

Objective: Obtain the total and infrared vertical profiles of upward, downward, and net radiation and the atmospheric radiation cooling. Determine the vertical lapse of temperature and water vapor in the free atmosphere.

38 Tower Program

Principal Investigator: H. A. Panofsky, Department of Meteorology, Pennsylvania State University, University Park, Pennsylvania 16802.

Objective: Compare the coherence of wind fluctuations with horizontal or vertical separation over a lake with corresponding statistics over land.

63 NCAR/DRI Buffalo (airplane) Program

Principal Investigator: J. W. Telford, Atmospheric Physics Laboratory, Desert Research Institute, University of Nevada, Reno, Nevada 89507.

Objective: Use of the NCAR/DRI Buffalo airborne measurement system for systematic documentation of the modifications of an air mass as it moves across Lake Ontario.

Canadian Tasks

5BL Direct Measurement of Energy Fluxes

Principal Investigator: M. Donelan, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objectives: Measure the vertical transfer of momentum, heat, and water vapor to (1) obtain accurate measurements of energy flux values for comparison with values from the IFYGL buoys, (2) improve the knowledge of exchange coefficients used in aerodynamic formulae, and (3) improve basic understanding of the exchange processes over a natural wave surface.

15BL Space Spectra in the Free Atmosphere

Principal Investigators: G. A. McBean, and E. G. Morrissey, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Using data from the T-33 airplane (as instrumented by the National Aeronautical Establishment), estimate the spatial variations of wind and temperature over a scale range of 1 to 100 km, and investigate the horizontal and vertical variation of the fluxes of momentum, heat, and moisture.

28BL Momentum, Heat, and Moisture Transfer

Principal Investigators: H. C. Martin, G. A. McBean, and R. J. Polavarapu, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Investigate the transfers of momentum, heat, and moisture in the atmospheric surface layer over Lake Ontario. This includes studies of the transfer mechanisms of the fluxes, the variation of the fluxes over 24- to 48-hour periods, the gradients of wind, temperature, and humidity to 12 meters, wave height and period as a function of wind, stability, and fetch, and the energy balance at the water surface. Parameterization of the fluxes in terms of single level observations will also be investigated.

29BL Space and Time Spectra

Principal Investigators: F. B. Muller, and C. D. Holtz, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Obtain data on temperature, humidity, pressure, wind speed and direction, and rainfall over the Toronto Research Meso-meteorological Network to calculate and compare space and time spectra for a selection of interesting periods.

44BL Analysis of Energy Fluxes by Aerodynamic Methods

Principal Investigator: F. C. Elder, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Calculate, from meteorological buoy measurements, the time- and space-averaged measurements of fluxes of sensible heat, latent heat and momentum, and compare the results with those from other methods of measurement (see 97BL).

75BL Wind and Temperature Fluctuations

Principal Investigators: S. D. Smith and E. G. Banke, Atlantic Oceanographic Laboratory, Environment Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

Objective: Measure fluxes of heat, momentum, and water vapor at the Niagara Bar by eddy flux methods, and compare these measurements, and wind velocity, temperature, and humidity spectra and co-spectra using two sets of sensors.

97BL Meteorological Buoy Measurements

Principal Investigator: F. C. Elder, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Operate a network of meteorological measurement systems on a buoy network, and process data for the data bank, to provide empirical data for computation of time- and space-averaged energy fluxes during IFYGL.

106BL Boundary Layer Investigations

Principal Investigators: G. A. McBean, Atmospheric Environment Service, Environment Canada, Downsview, Ontario M3H 5T4; and M. Miyake, Institute of Oceanography, University of British Columbia, Vancouver, British Columbia.

Objective: Investigate the structure of the wind (including turbulence), temperature, and humidity fields over the Lake Ontario region to 500 m altitude using tethered balloon systems.

107BL Air Pollution Sinks on Lake Ontario

Principal Investigators: D. M. Welpdale and R. W. Shaw, Air Quality Research Branch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objective: Estimate the downward transport of air pollutants from the air over Lake Ontario into the water using SO_2 gradient measurements and water samples from the barge at the Niagara Bar and precipitation samples collected along the Canadian shoreline of the lake.

113BL Atmospheric Heat and Water Budget

Principal Investigator: R. M. Holmes, ERA Instruments, Calgary, Alberta.

Objective: Determine the atmospheric heat and water budget of the lake and basin, using sensors and aircraft platforms.

OTHER TASKS

United States Tasks

61 Clouds, Ice, and Surface Temperatures

Principal Investigator: A. E. Strong, National Environmental Satellite Service, NOAA, Suite 300, 3737 Branch Avenue, Hillcrest Heights, Maryland 20031.

Objective: Routine observations of clouds, ice, and surface temperatures from NOAA satellites.

70 Evaluation of ERTS Data for Certain Hydrological Uses

Principal Investigators: D. R. Wiesnet, and D. F. McGinnis, National Environmental Satellite Service, NOAA, 3737 Branch Avenue, Hillcrest Heights, Maryland 20031.

Objective: Assess quantitatively the ERTS satellite data for a temperate region lake and its drainage basin in terms of hydrologic information content, relating ground truth to the spectral bands sensed, ground resolution, etc. Coincident use of ITOS-D imagery and data will permit evaluation of the effect of the 18-day revisit cycle on the monitoring of hydrologic phenomena.

Canadian Tasks

1F Remote Sensing

Principal Investigator: K. P. B. Thomson, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Investigate the time scale and other features of the dominant thermal features and their relation to large-scale water circulation in Lake Ontario, using remote sensors in a high-altitude aircraft and the ERTS satellite.

18 Climatological Network

Principal Investigator: J. A. W. McCulloch, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Objectives: Operate and maintain the existing basin climatological network for precipitation and temperature data (daily values); and augment the existing network with (a) the addition of five new stations, (b) the installation of additional recording rain gauges at existing stations, and (c) the addition of 25 barographs at existing stations. All stations are located in the land portion of the Lake Ontario drainage basin in Canada.

30F IFYGL Operations - CCGS Porte Dauphine

Principal Investigator: G. K. Rodgers, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Maintain a basic field staff and data handling staff for the general survey work scheduled for the CCGS Porte Dauphine through the Field Year; provide technician assistance to researchers using this ship; and provide basic equipment and supplies as necessary.

68F CCIW Supporting Resources

Principal Investigator: Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

Objective: Provide a variety of devices, facilities, and services in support of the IFYGL programs. This includes research buoys and mooring gear, meteorological instruments, ships, and data processing.

79F Bathymetric Surveys - Lake Ontario

Principal Investigator: T. D. W. McCulloch, Canada Centre for Inland Waters, Environment Canada, Burlington, Ontario L7R 4A6.

Objective: Carry out a bathymetric survey of Lake Ontario during IFYGL at a scale of 1:200,000, omitting areas of less than 30 meters depth which will require a larger-scale survey.

94 Data Retransmission by Satellite

Principal Investigator: H. MacPhail, Canada Centre for Inland Waters, Environment Canada, Burlington, Ontario L7R 4A6.

Objective: Measure lake parameters in a remote or hostile environment, and relay the data in real time via satellite, using buoys with sensors and a monitor receiver; and collect data via the U.S. GOES satellite at a later stage.

APPENDIX B

IFYGL PERSONNEL

NOTE: Where dates are listed next to the names in this section, they are the dates of first appointment to (and resignation from) the particular position. If only one date is listed, it is presumed that the person is still occupying the position. Names are generally listed in alphabetical order, although the chairmen of the various committees and panels are given first, and past members (as of the Steering Committee) are listed after incumbents.

The organizations listed with the names are, generally, correct as of late 1973. However, in the case of former members of various groups, or members of groups that are no longer active, the affiliation listed is as of the time of membership or activity. The same person may be listed elsewhere in an active capacity with a different affiliation.

IFYGL STEERING COMMITTEE

United States

8/66- W. J. Drescher (Chairman)
Planning Officer
Region V
U.S. Department of the Interior

6/71- L. D. Attaway
Deputy Assistant Administrator for Research and Environmental Assessment
Environmental Protection Agency

4/71- E. J. Aubert
Director
IFYGL Project Office
National Oceanic and Atmospheric Administration

8/66- D. C. Chandler
Director, Great Lakes Research Division
University of Michigan

8/66- A. P. Pinsak
Chief, Water Characteristics Branch
Lake Survey Center
National Oceanic and Atmospheric Administration

8/66-6/67 D. L. Harris
Coastal Engineering Research Center
U.S. Army Corps of Engineers

4/71-6/71 F. D. Mayo
Regional Administrator
Region V
Environmental Protection Agency

2/68-4/71 E. M. Rasmusson
Bomap Analysis Group Rx9
National Oceanic and Atmospheric Administration
Center for Experiment Design and Data Analysis

Canada

8/66- T. L. Richards (Chairman)
Superintendent of Hydrometeorology
Atmospheric Environment Service
Environment Canada

2/68- J. P. Bruce
Director
Canada Centre for Inland Waters
Environment Canada

5/71- W. J. Christie
Glenora Fish Station
Ontario Ministry of Natural Resources

10/72- D. N. Jeffs
Ontario Ministry of the Environment

8/66- D. F. Witherspoon
Engineer-in-Charge
Great Lakes - St. Lawrence Study Office
Environment Canada

8/66-6/68 A. T. Prince
Director
Inland Waters Branch
Department of Energy, Mines and Resources

8/66-8/72 A. K. Watt
Assistant General Manager
Ontario Water Resources Commission

Alternates (all United States)

1/67- 1/67	J. C. Ayers (for Chandler)	7/72-	T. T. Davies (for Attaway) Grosse Ile Laboratory Environmental Protection Agency
4/71- 6/71	D. J. Casey (for Mayo) Lake Ontario Basin Office Environmental Protection Agency	8/71- 7/72	N. R. Glass (for Attaway) Office of Research and Monitoring Environmental Protection Agency

JOINT MANAGEMENT TEAM

(First Meeting 12 October 1971)

	United States		Canada
10/71-	E. J. Aubert (Co-Chairman) NOAA/IFYGL	10/71-	T. L. Richards (Co-Chairman) AES/HM
3/72-	T. T. Davies EPA	10/71-	J. P. Bruce CCIW
10/71-	L. D. Drury NOAA/IFYGL	10/71-	W. J. Christie OME/GFS
10/71-	Andrew Robertson NOAA/IFYGL	10/72-	D. N. Jeffs OME
10/71- 6/73	W. S. Barney NOAA/IFYGL	10/71-	D. F. Witherspoon GLSLSO
10/71- 6/73	Terry de la Moriniere NOAA/IFYGL	10/71- 8/72	A. K. Watt OME
3/72- 6/73	Dewey Rushford NOAA/IFYGL		
10/71- 6/73	O. E. Scribner NOAA/IFYGL		

Alternates

12/72-	N. A. Thomas (for T. Davies) EPA	10/71- 8/72	D. N. Jeffs (for Watt) OME

EX-OFFICIO AND LIAISON MEMBERS - IFYGL Steering Committee, Joint Management Team

United States

8/66- L. A. Heindl
Executive Secretary
U.S. National Committee for the IHD
National Research Council,
National Academy of Sciences

12/67- 6/71 W. H. Brutsaert
Cornell University

2/69- J. E. Bunch
U.S. Lake Survey
U.S. Army Corps of Engineers

1/70- 4/71 J. B. Hall
U.S. Lake Survey
U.S. Army Corps of Engineers

1/71- 6/73 Dwight Metzler
Deputy Commissioner
New York State Department of Environmental Conservation

8/66- 12/67 W. C. Walton
Director, Water Resources Research Center
University of Minnesota

Canada

12/67- I. C. Brown
Executive Secretary
Canadian National Committee for the IHD
Inland Waters Directorate
Environment Canada

1/70- 10/71 W. J. Christie
Glenora Fisheries Station
Ontario Ministry of Natural Resources

8/65- 12/67 J. F. Fulton
Water Resources Branch
Department of Energy, Mines and Resources

COORDINATORS

United States

4/71- C. J. Callahan
NOAA/IFYGL

10/68- 4/71 S. J. Bolsenga
CE/USLS

10/68- 4/71 R. N. Kelley (ass't.)
CE/USLS

Canada

9/73- Brian O'Donnell
AES

1/73- 9/73 J. R. Sandilands
AES

2/69- 3/73 Joseph MacDowall
CCIW

NOTE: The Coordinators are ex-officio members of the Steering Committee, the Joint Management Team, and all Panels, Working Groups, and Support Groups.

SCIENTIFIC PROGRAM PANEL CHAIRMEN

United States		Canada
B. G. DeCooke, COE/DD	Terrestrial Water Balance	D. F. Witherspoon, DE/GLSLSO
E. M. Rasmusson, NOAA/CEDDA	Lake Meteorology and Evaporation	J. A. W. McCulloch, DE/AES
A. P. Pinsak, NOAA/LSC	Energy Balance	G. K. Rodgers, CCIW/DE
J. H. Saylor, NOAA/LSC (J. G. Housley, COE) *(A. P. Pinsak, NOAA/LSC)	Water Movement	E. B. Bennett, CCIW (H. S. Weiler, CCIW)
N. A. Thomas, EPA/ORM (N. A. Jaworski, EPA) (D. C. Chandler, UM/GLRD)	Biology & Chemistry	W. J. Christie, OMNR/GFS
J. Z. Holland (E. M. Rasmusson, NOAA/CEDDA) (J. A. Businger, University of Washington)	Atmospheric Boundary Layer	F. C. Elder, CCIW

* Names in parentheses are former panel chairmen

OBSERVERS AND ADVISERS - IFYGL Steering Committee, Joint Management Team

United States

L. Bajorunas, COE/USLS
J. E. Bunch, COE/USLS
A. L. Cochran, COE
L. T. Crook, GLBC
K. W. Foulke, NOAA/IFYGL
J. G. Housley, COE
D. Hoydysh, NOAA/IFYGL
J. O. Ludwigson, USNC/IHD
J. M. Miller, USA/COE
R. Paine, NOAA
S. Peterson, NOAA/LSC
D. C. N. Robb, GLBC
R. Williams, NOAA/LSC

Canada

A. S. Atkinson, CCIW/ops.
D. J. Cooper, CCIW/ops.
G. T. Csanady, UWtr
F. L. deGrasse, CCIW
H. L. Ferguson, DE/AES
W. A. Glooschenko, CCIW/FRB
A. R. Kirby, CCIW
F. J. Philbert, CCIW/IWD/ Water Quality Laboratory
K. P. B. Thomson, CCIW/GLD
W. J. Traversy, CCIW/IWD/ Water Quality Laboratory
R. A. Vollenweider
P. R. Youakim, CCIW/ops.

AD HOC UNITED STATES/CANADIAN STUDY GROUP ON FEASIBILITY OF IFYGL

Urbana, Illinois
11 & 12 November 1965

Canada

J. P. Bruce	Superintendent of Hydrometeorology, Canada Department of Transport (now Director, CCIW)
J. F. Fulton	Assistant Secretary, CNC/IHD; Canada Dept. of Northern Affairs and National Resources (became Department of Mines and Technical Surveys)

United States

W. C. Ackermann	Vice Chairman, USNC/IHD and Chief, Illinois State Water Survey
W. H. Durum	Assistant Chief, Water Quality Branch, Water Resources Division, U.S. Geological Survey
M. A. Kohler	Chief Hydrologist, U. S. Weather Bureau

SCIENTIFIC ADVISORY WORKING GROUPS

These working groups were established in January, 1967, to design a coherent, comprehensive scientific program for IFYGL, and to advise the Steering Committee concerning the suitability of proposed tasks and projects. The working groups were based on four subcommittees formed by the Steering Committee on August 9, 1966, and were intended to bring together a diverse group of physical scientists active in research on and around the Great Lakes.

The original name of each working group is given first, with the later version in parentheses. Note that the IFYGL Steering Committee representatives are not necessarily chairmen.

Atmospheric Water Budget (Lake Meteorology and Evaporation)

J. A. W. McCulloch (Chairman), AES
S. H. Brown, USA/Electronics Command
J. Clodman, DOT/MB
A. Cole, UM/Dept. of Meteorology and Oceanography
C. R. Cunn, WB/Eastern Region
F. C. Elder, CCIW/GLD
H. L. Ferguson, DOT/MB
W. F. Hall, ESSA
G. E. Harbeck, Jr., USGS
*D. L. Harris (SC rep.), ESSA/IO
J. D. Holland, DOT/MB
R. H. Holmes, DEMR/IWB
I. Jiusto, SUNY/Albany
W. J. Joroz, ODH/APSC
J. S. Marshall, MU
G. H. McVehil, CAL
F. B. Muller, DOT/MB
R. E. Munn, DE/AES/MB/MRU
*T. L. Richards (Alt. SC rep.), AES/HMA
V. J. Schaefer, SUNY/Albany
L. Shenfeld, ODH/APCS
G. E. Stout, ISWS
R. B. Sykes, SUNY/Oswego
K. W. Veigus, WB/Eastern Region
H. S. Weiler, CCIW/GLD

* (Members of August '66 Steering Committee subcommittee.)

Surface and Groundwater Budget (Terrestrial Water Balance)

*D. F. Witherspoon (Chairman, SC rep.), GLSLSO
G. R. Ayer, USGS
J. E. Bunch, CE/USLS
R. W. Carter, USGS
J. A. Davies, McM
B. G. DeCooke, CE/USLS
*W. J. Drescher (Alt. SC rep.), USGS
C. Haefeli, DEMR/IWB
R. C. Hore, OME/WQMB
J. G. Irbe, AES/LIU
D. N. Jeffs, OME/WQMB
R. K. Lane, DEMR/IWB
F. I. Morton, DEMR/IWB
R. H. Musgrove, USGS
R. C. Ostry, OME/WQMB
G. G. Parker, USGS
R. Pentland, DEMR/IWB/Eng. Div.
R. G. Pirie, UWisc/Milwaukee
T. L. Richards, DEMR/IWB
G. K. Rodgers, UT/GLI
B. E. Russell, DEMR/IWB/WSC
H. Ryckborst, DEMR/IWB
M. Sanderson, UWin
K. Symons, OME/WQMB
J. H. Thomas, ESSA/WB
*A. K. Watt (Alt. SC rep.), OME
G. E. Williams, USGS

* (Members of August '66 Steering Committee subcommittee.)

Energy Balance

*G. K. Rodgers (Chairman, Alt. SC rep.), UT/GLI
S. J. Bolsenga, COE/USLS
J. A. Davies, McM
R. K. Lane, CCIW/GLD
R. Latimer, DOT/MB
*A. P. Pinsak (SC rep.), NOAA/LSC
T. L. Richards, AES/HMA
J. T. Scott, SUNY/Albany

* (Members of August '66 Steering Committee subcommittee.)

Lake Circulation and Diffusion

G. T. Csanady (Chairman), UWt
D. V. Anderson, UT
G. E. Birchfield, NU
D. J. Casey, EPA (formerly FWPCA)
*D. C. Chandler (SC rep.), UM/GLRD
G. C. Gill, UM
J. G. Housley, COE/Off of Chief
S. Ince, NRCC
J. A. W. McCulloch, AES/LIU
C. H. Mortimer, UWisc
V. E. Nobel, UM/GLRD
*A. T. Prince (Alt. SC rep.), DE/IWB
R. A. Ragotzkie, UWisc
G. K. Rodgers, UT/GLI
H. S. Weilder, DEMR/GLRD

* (Members of August '66 Steering Committee subcommittee.)

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(Replaced Scientific Advisory Working Groups in early 1970.)

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M. A. Estoque, UMiami	R. E. Munn, AES/AQRS
J. W. Telford, UNev/DRI	S. D. Smith, BIO
	M. S. Webb, AES/LIU

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NOTE: Membership in these groups was largely an _ad hoc_ arrangement, depending on the immediate problems to be met. The chairmen, however, remained in office, serving as special-interest coordinators.

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Remote Sensing	
V. V. Salomonson, NASA/GSFC	K. P. B. Thomson, CCIW/IWD/HD
Data Management	
L. D. Drury, NOAA/CEDDA (IFYGL)	H. S. Weiler, CCIW/IWD
Publications	
W. J. Drescher, DI/Region 5	T. L. Richards, DE/AES
Public Information	
R. D. Paine, NOAA	A. R. Kirby, DE/CCIW

Appendix C

ORGANIZATIONS INVOLVED IN IFYGL

NOTE: This list of governmental, academic, and private organizations is intended to name each of the specific groups that participated actively in the International Field Year for the Great Lakes. Although a considerable effort has been made to give credit where it is due, these entries may not entirely reflect the nature of those groups' relationships with other parts of their respective governmental or other parent organizations.

GOVERNMENT -- NATIONAL

Canada

<u>Department of Energy, Mines and Resources</u>
- Canada Centre for Remote Sensing
- Great Lakes Research Division
- Geological Survey of Canada

<u>Department of the Environment (Environment Canada)</u>
- Atmospheric Environment Service
  - Central Services Directorate
    - Hydrometeorology and Marine Applications Division
- Environmental Management Service
  - Inland Waters Directorate
    - Canada Centre for Inland Waters
    - Great Lakes - St. Lawrence Study Office
    - Water Survey of Canada
      - Tides and Water Levels Section
    - Canadian Wildlife Service
- Fisheries and Marine Service
  - Marine Sciences Directorate
    - Canadian Hydrographic Service
    - Atlantic Oceanographic Laboratory
    - Fisheries Research Board

<u>National Museum of Canada</u>

United States

<u>Department of Commerce</u>
- National Oceanic and Atmospheric Administration
  - Atlantic Oceanographic and Meteorological Laboratory
  - Center for Experiment Design and Data Analysis
  - Environmental Research Laboratories
  - Environmental Satellite Service
  - Lake Survey Center
  - National Weather Service
  - Research Flight Facility

<u>Department of Defense</u>
- U.S. Army: Corps of Engineers (Detroit District)
- U.S. Air Force: Air Weather Service

<u>Department of the Interior</u>
- Bureau of Sport Fisheries and Wildlife
  - Great Lakes Fisheries Laboratory
- U.S. Geological Survey

<u>Department of Transportation</u>
- U.S. Coast Guard
- Federal Aviation Agency

Canada

National Research Council of Canada
- Canadian National Committee for the International Hydrological Decade
- National Aeronautical Establishment

Ministry of Transport
- Canadian Marine Transportation Agency
  - Prescott Marine Agency

United States

Environmental Protection Agency
- Rochester Field Office of Region II
- Grosse Ile Field Station of the National Environmental Research Center, Corvallis, Oregon (Office of Research and Development)

National Aeronautics and Space Administration
- Lewis Research Center
- Environmental Research Laboratories

National Science Foundation

GOVERNMENT -- STATE/PROVINCIAL

Ontario Department of Health
- Air Pollution Control Service

Ontario Ministry of the Environment
- Division of Laboratories and Research
- Division of Water Resources
  - Water Quality Branch
  - Water Quantity Management Branch
    - River Basin Research Section

Ontario Ministry of Natural Resources
- Glenora Fisheries Station
- Lake Erie Fisheries Research Station

Royal Ontario Museum

Illinois State Water Survey

New York State Department of Environmental Conservation

NON-GOVERNMENTAL -- ACADEMIC

Canada

Dalhousie University

McGill University

McMaster University
  Centre for Applied Research and Engineering Design
  Department of Geography

Queen's University

Trent University

University of British Columbia
  Institute of Oceanography

University of Guelph

University of Toronto
  Great Lakes Institute
  Institute of Environmental Sciences and Engineering

University of Waterloo

University of Windsor

Denmark

University of Copenhagen

United States

Cape Fear Technical Institute

Colorado State University

Cornell University
  Cornell Aeronautical Laboratory

Manhattan College

Northwestern University

Pennsylvania State University

State University of New York
  Buffalo
  Albany
  Oswego

University of Miami (Florida)

University of Michigan
  Great Lakes Research Division
  Willow Run Laboratory

University of Nevada
  Desert Research Institute

University of Rochester

University of Washington

University of Wisconsin
  Great Lakes Center
  University of Wisconsin-Milwaukee

Woods Hole Oceanographic Institution

NON-GOVERNMENTAL - PRIVATE

Canada

ERA Instruments

United States

Calspan Corporation

Center for the Environment and Man

General Electric, Inc.

National Academy of Sciences-National Research Council
United States National Committee for the International Hydrological Decade

Appendix D

ABBREVIATIONS & ACRONYMS

ABL	Atmospheric Boundary Layer Program
AES	Atmospheric Environment Service, DE
AOL	Atlantic Oceanographic Laboratories, DE (at BIO)
AOML	Atlantic Oceanographic and Meteorological Laboratory, NOAA
APCS	Air Pollution Control Service, ODH
AQRS	Air Quality Research Station, AES
ART	Airborne Radiation Thermometer
ASU	Airborne Sensing Unit of CCRS
ATP	Adenosine Triphosphate
AWB	Atmospheric Water Balance Project, of LME Program
AWIU	Air-Water Interaction Unit, AES
AWS	Air Weather Service, USAF
BC	Biology and Chemistry Program
BIO	Bedford Institute of Oceanography (site of AOL)
BLS	Biological Limnology Section, CCIW
BSFW	(U.S.) Bureau of Sport Fisheries and Wildlife, DI
BT	Bathythermograph
CAL	Cornell Aeronautical Laboratory, CU
CAPPI	Constant Altitude Plan Position Indicator, of precipitation radar
CARED	Centre for Applied Research and Engineering Design (McMaster University)
CCGS	Canadian Coast Guard Ship
CCIW	Canada Centre for Inland Waters, DE
CCRS	Canada Centre for Remote Sensing, DEMR
CE or COE (DD)	U.S. Army Corps of Engineers (Detroit District)
CEDDA	Center for Experiment Design & Data Analysis, NOAA
CEM	Center for the Environment
CF 100	CF 100 Aircraft of CCRS
CFTI	Cape Fear (N.C.) Technical Institute
CHS	Canadian Hydrographic Service, MSD/FMS/DE
CLS or CL	Chemical Limnology Section, CCIW
CNC/IHD	Canadian National Committee for the IHD
CODC	Canadian Oceanographic Data Centre
CSS	Canadian Survey Ship
CU	Cornell University

DAPP	Data Acquisition & Processing Program (USAF Weather Satellite)
DC	(U.S.) Department of Commerce
DE (or DOE)	Department of the Environment (Environment Canada)
DEMR	Department of Energy, Mines & Resources, Canada
DI	(U.S.) Department of the Interior
DLS	Descriptive Limnology Section of CCIW
DOT	Department of Transportation
DRI	Desert Research Institute, UNev
DSE	Division of Sanitary Engineering, OME
DWR	Division of Water Resources, OME

EB	Energy Balance Program
EBT	Electronic Bathythermograph
EC	Environment Canada (see DE)
EMS	Environmental Management Service, DE
EPA	(U.S.) Environmental Protection Agency
ERL	Environmental Research Laboratories, NOAA
ERTS	Earth Resources Technology Satellite
ESS (NESS)	National Environmental Satellites Service, NOAA
ESSA	(U.S., former) Environmental Science Services Administration (now largely in NOAA)

FAA	(U.S.) Federal Aviation Agency
FDRU	Forecast Development Research Unit, AES
FMS	Fisheries and Marine Service, DE
FRB	Fisheries Research Board, FMS/DE

GFS	Glenora Fisheries Station, OMNR (formerly ODLF)
GLBC	Great Lakes Basin Commission
GLC	Great Lakes Centers, UWisc
GLD	Great Lakes Division, CCIW (see "LD")
GLFL	Great Lakes Fisheries Laboratory, DI
GLI	Great Lakes Institute, UT
GLRC	Great Lakes Research Center, LSC/NOAA (formerly DD/COE)
GLRD	Great Lakes Research Divison, UM, or DEMR
GLSLSO	Great Lakes-St. Lawrence Study Office, IWD/EMS/DE
GSC	Geological Survey of Canada, DEMR
GSFC	Goddard Space Flight Center, NASA

HD	Hydraulics Division, CCIW/IWD
HMA	Hydrometeorology and Marine Applications Division, AES
HRD	Hydrometeorological Research Division, AES
HSD	Hydrologic Sciences Division, IWD/DE

IBP	International Biological Program
IESE	Institute of Environmental Sciences and Engineering, UT
IFYGL	International Field Year for the Great Lakes
IGLD	International Great Lakes Datum
IHD	International Hydrolcgical Decade
IJC	International Joint Commission
IO	Institute for Oceanography
IRLS	Interrogation, Recording and Locating Sub-system of the (U.S.) Nimbus satellites
ISWS	Illinois State Water Survey
IWD	Inland Waters Directorate, EMS/DE (formerly of DEMR)

JMT	Joint Management Team, IFYGL

LD	Lakes Division, CCIW
LEFRS	Lake Erie Fisheries Research Station, OMNR
LGS	Limnogeology Section, CCIW
LMA	Lakes and Marine Applications Section, AES
LME	Lake Meteorology and Evaporation Program
LRC	Lewis Research Center, NASA
LRS	Lakes Resources Subdivision, CCIW
LSC	Lake Survey Center, NOAA/DC

MB	Meteorological Branch, MOT (now AES/DE)
MC	Manhattan College (N.Y.)
McM	McMaster University
MOT	Ministry of Transport (Canada)
MRU	Micrometeorological Research Unit, MB
MSD (or MS)	Marine Sciences Directorate, DE
MU	McGill University

NAE	National Aeronautical Establishment, NRCC
NARC	National Atmospheric Radiation Centre, AES
NAS	National Academy of Sciences, U.S.
NASA	(U.S.) National Aeronautics and Space Administration
NCAR	(U.S.) National Center for Atmospheric Research
NESS	National Environmental Satellite Service, NOAA
n.m.	Nautical mile
NMC	National Museum of Canada
NOAA	(U.S.) National Oceanic & Atmospheric Administration, DC
NRCC	National Research Council of Canada
NSF	(U.S.) National Science Foundation
NU	Northwestern University
NWS	(U.S.) National Weather Service, NOAA
NYSDEC	New York State Department of Environmental Conservation

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ODH	Ontario Department of Health
(ODLF)	(Ontario Department of Lands and Forests)
OME	Ontario Ministry of the Environment (supplants OWRC)
OMNR	Ontario Ministry of Natural Resources (supplants ODLF)
OOPS	Ontario Organic Particle Study (a CCIW project)
ops.	operations
ORM	Office of Research and Monitoring, EPA
(OWRC)	(Ontario Water Resources Commission)

PCB	polychlorobiphenyls
PLS	Physical Limnology Section, CCIW
PPB	parts per billion (10^9)
PPM	parts per million (10^6)

RBRB	River Basin Research Branch, OME
RFF	Research Flight Facility, NOAA
RIU	Radiation and Ice Unit, AES
ROM	Royal Ontario Museum

SC	(IFYGL) Steering Committee
STORET	Data and Information System of EPA
SUNY	State University of New York (at various locations)

TSAR	Time-series Storage and Retrieval System
TWB	Terrestrial Water Balance Program
TWL	Tides and Water Levels Section, WSC

UBC	University of British Columbia
UG	University of Guelph
UM	University of Michigan
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNev	University of Nevada
USA	United States Army
USAF	United States Air Force
USCG	U.S. Coast Guard, DOT
USGS	U.S. Geological Survey, DI
USLS	U.S. Lake Survey, COE (now LSC/NOAA)
USNC/IHD	United States National Committee for the IHD
UT	University of Toronto
UWt	University of Waterloo
UWin	University of Windsor
UWisc	University of Wisconsin

WB	(U.S.) Weather Bureau (now NWS/NOAA)
WCB	Water Characteristics Branch, LSC/NOAA
WHOI	Woods Hole Oceanographic Institution
WM	Water Movement Program
WMO	World Meteorological Organization
WQB	Water Quality Branch, OME
WQD	Water Quality Division, CCIW
WQMB	Water Quantity Management Branch, OME
WRL/UM	Willow Run Laboratory, UM
WSC	Water Survey of Canada, IWD/EMS/DE

Appendix E

THE ANDERSON LETTER

NOTE: The following letter was sent by Dr. D. V. Anderson of the University of Toronto to the Canadian National Committee for the IHD. It is particularly interesting to compare the details of the proposal with what has actually happened. Remembering that Dr. Anderson played a minor formal role in the many subsequent detailed program planning meetings, it is remarkable how closely the IFYGL has in fact followed the ideas expressed in his letter.

"Mr. R. H. Clark, Secretary,
IHD - Canadian National Committee,
150 Wellington Street, April 5, 1965
Ottawa 4, Ontario

Dear Mr. Clark:

Re: International Field Year in the Great Lakes

At the recent (29-30 March) Eighth Conference on Great Lakes Research in Ann Arbor, I was a member of a panel on cooperative programmes. Its moderator, Dr. G. K. Rodgers (Great Lakes Institute, U. of T.) had asked us to come prepared with concrete suggestions. Responding to his invitation, I made a proposal which seems to me, and to a few colleagues whom I have consulted, worthwhile putting forward to competent authorities for serious consideration. As your National Committee would be a principal judge I thought this would be a good time to describe it to you.

1. Proposal - To hold a cooperative, international "Field Year" in Great Lakes limnological studies under the (partial) auspices of the IHD.

2. Background - A proposal similar in intent although differing in context was put forward by Professor Portman, University of Michigan, a few years ago. He in turn took the O'Neill Nebraska Experiment as a model. (Ref. Exploring the Atmosphere's First Mile. Pergamon Press, 1957.) Various cooperative ventures have been and are being undertaken in the Lakes now, but the mantle of the IHD would surely strengthen Great Lakes research.

3. Principal Location - Lake Ontario. The choice of a lake upon which to focus attention is not critical in any one measure. Taking a few together, they favour Lake Ontario decidedly.

   (a) International lake (Lake Michigan ruled out).
   (b) Deep and therefore representative of other deep lakes (Erie ruled out)
   (c) Reasonably simple shape (Lake Huron and Georgian Bay ruled out).
   (d) Reasonably accessible (Superior ruled out).
   (e) Reasonably well described (Lake Ontario is best described of all).

4. Year - 1967.

5. Specific Purposes -

   (a) To improve observational, experimental and theoretical techniques in Lakes Research. (This would include education and guidance of workers.)

   (b) To encourage projects made possible by pooling equipment, skills, and analytical facilities.

6. Projects -

   (a) A few large projects would be chosen for concentration in Lake Ontario. These would be of the following sort: atmospheric water balance project (already proposed by Meteorological Service); infra red radiometry; circulation associated with "thermal bar'; Texas type limnological tower; air-sea interaction; large scale diffusion studies; buoy measurements (already being done); investigation of lake ice.

   (b) Many small scale projects would be given priority. These need not be done on Lake Ontario. (some would be laboratory based or on theoretical subjects) but would be chosen to fit as small segments within the main projects. They would be such as could be undertaken by smaller, local institutions. For example, local circulation of Niagara River in Lake Ontario.

   (c) Oceanographic research groups (Canadian, U.S. and foreign) would be invited to lend staff, and to send up research vessels for short periods. The educational value of this is obvious but special projects could be undertaken, in a well integrated programme. (There are already examples of the benefits from this kind of cooperation.)

(d) Manufacturers and consultants would be given field-days for demonstration of instruments and skills.

(e) Workshops and seminars would be held on specific projects.

(f) Through the initial help of specialists, groups with interest and ability would be properly launched on field, laboratory and theoretical projects.

7. Consequences - Great Lakes problems in the main have proven to require more than the unilateral power of single groups. Cooperative efforts are essential, in the public interest, and all work should be vetted by experts. That this has not been so has caused much waste and inefficiency. One year's concentrated joint attack on one lake should give immediate improvement in technique and show the power and limitations of the best methods available. Great Lakes research workers have not been able to avail themselves of the best and the standard of activity has not always been commensurate with the importance of the work. The results of a concordance of effort would be far reaching in limnology, and in view of the size of the Lakes problem, the IHD would both strengthen it and be strengthened.

While the proposal is a broad one, please note that it does not necessarily involve large and new funds. Rather it requires only doing "this, here" rather than "that, there" within one year.

The project could only be a success if it were enthusiastically and widely supported. I am pessimistic about the response to this proposal, but I believe that agencies that cannot cooperate rather generously are probably not going to contribute in just proportion to the public weal. Perhaps I could say, not tendentiously but provocatively, "If this project is not supported, it will be an indication that we shall have to content ourselves with less than the best in laying foundations for management of the Lakes."

As I have no formal position in this please treat this as a personal brief for your thought and, hopefully, for your attention.

Since there is an immediate opportunity of sounding Canadian opinion at the C.C.O. meetings at month's end, I have invited Dr. Rodgers to discuss this proposal with his superiors.

As you know Dr. Langford is a member both of your Committee and the C.C.O. I have also given copies of this letter to the Canadian Co-chairman of physical studies in the Great Lakes (D. K. A. Gillies), and to Dr. V. Noble of the University of Michigan who has expressed interest in the idea.

Yours truly,

(signed)

D. V. Anderson"